How Well Do **Advanced Placement** Students Perform on the **TIMSS** Advanced Mathematics and Physics Tests?

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June, 2001

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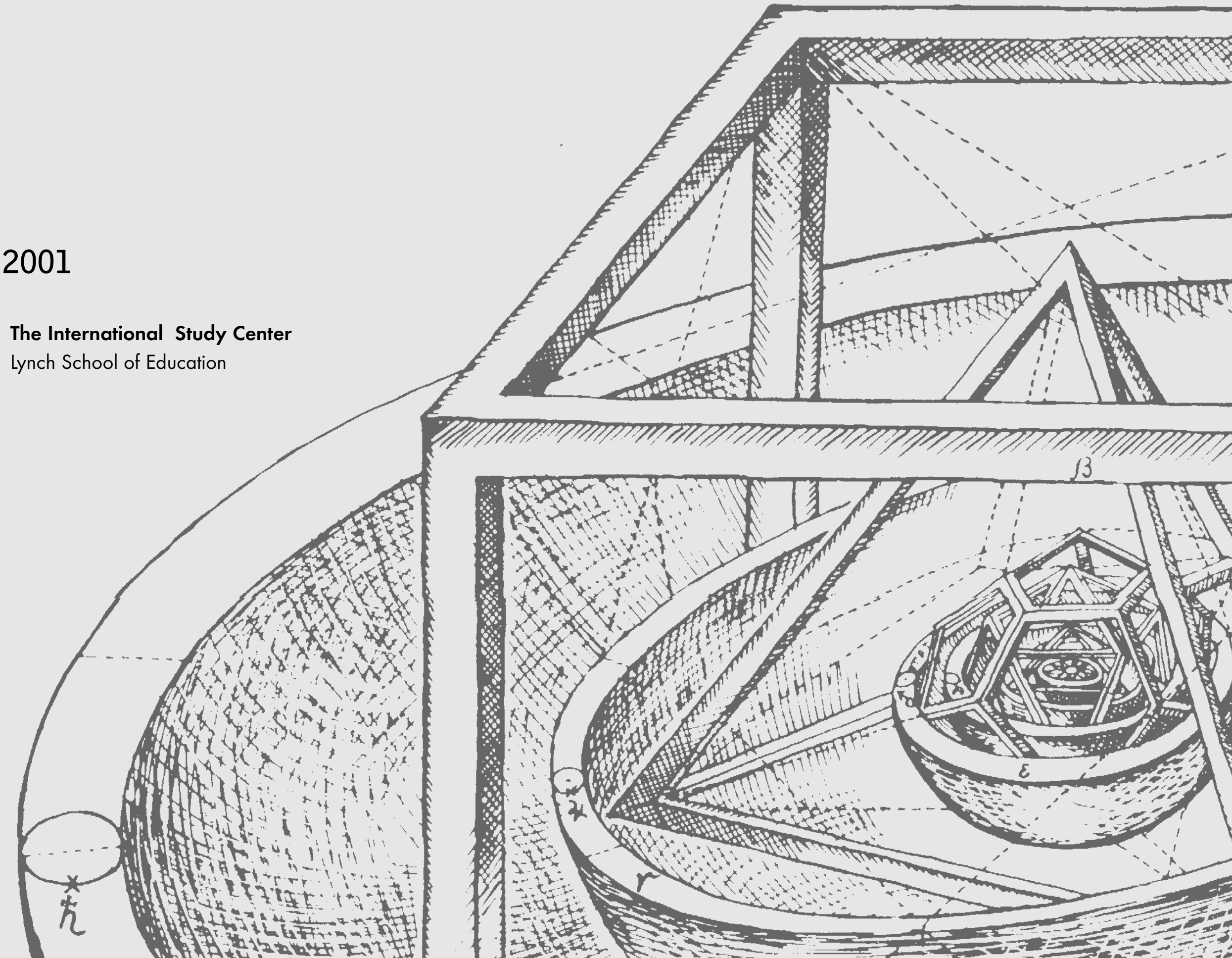

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Funding for this study was provided by The College Board.

Funding for the international coordination of TIMSS is provided by the U.S. National Center for Education Statistics, the U.S. National Science Foundation, the IEA, and the Canadian government. Each participating country provides funding for the national implementation of TIMSS.

Cover and book design by **Jose R. Nieto**.

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Text set in ITC Slimbach, designed by Robert Slimbach.

Captions and headings set in Bell Gothic, designed by Chauncy Griffith.

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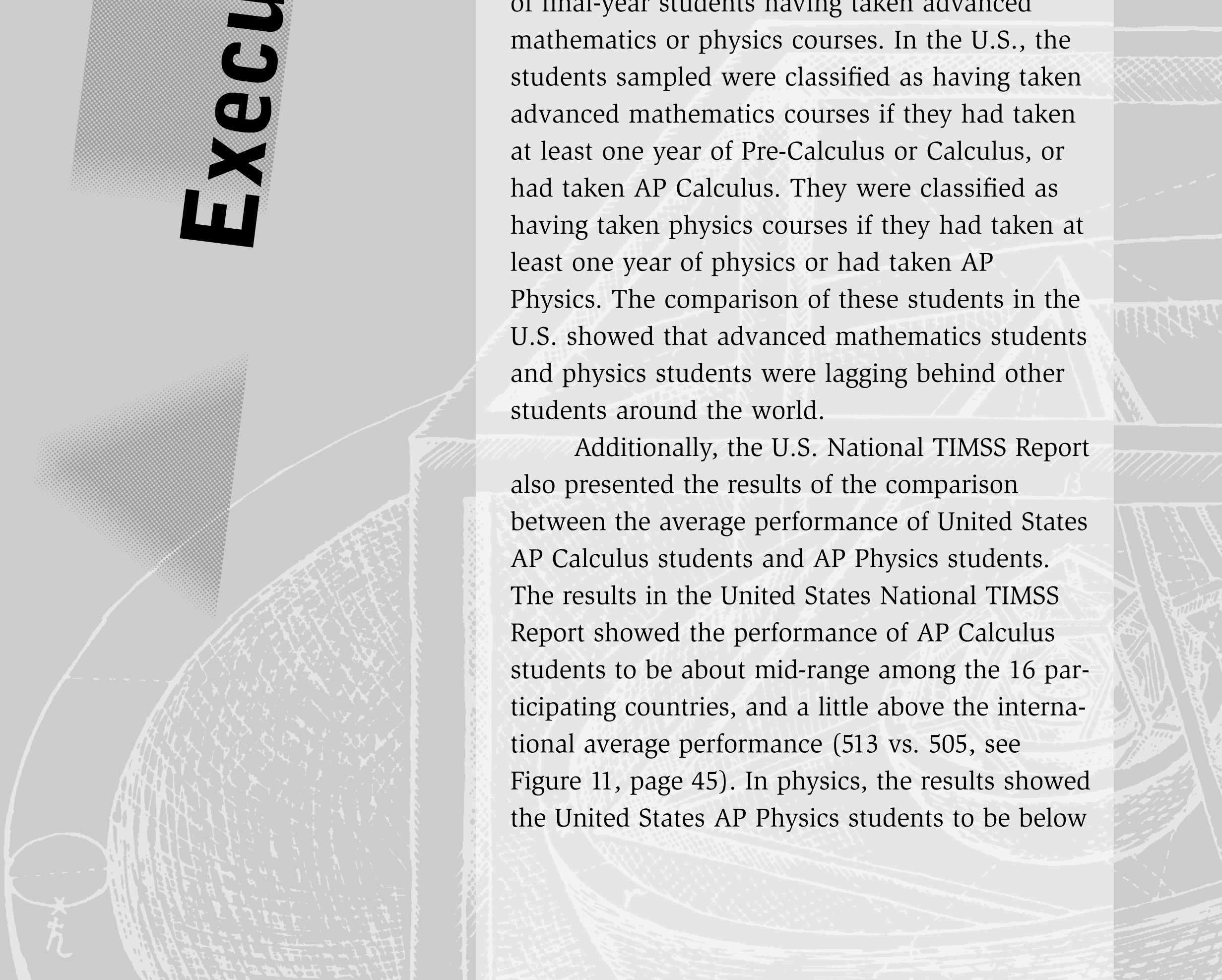

The Third International Mathematics and Science Study (TIMSS) showed that United States twelfth-grade students in 1995 were, on average, not leading, but lagging behind other students around the world in mathematics and science achievement. Additionally, the United States students ranked last in physics achievement by the final year of secondary school and ranked second to last in advanced mathematics achievement when compared to students with similar courses of study.

In the United States National TIMSS Report released in February 1998, data were presented comparing the average performance on the TIMSS Advanced Mathematics and Physics tests of final-year students having taken advanced mathematics or physics courses. In the U.S., the students sampled were classified as having taken advanced mathematics courses if they had taken at least one year of Pre-Calculus or Calculus, or had taken AP Calculus. They were classified as having taken physics courses if they had taken at least one year of physics or had taken AP Physics. The comparison of these students in the U.S. showed that advanced mathematics students and physics students were lagging behind other students around the world.

Additionally, the U.S. National TIMSS Report also presented the results of the comparison between the average performance of United States AP Calculus students and AP Physics students. The results in the United States National TIMSS Report showed the performance of AP Calculus students to be about mid-range among the 16 participating countries, and a little above the international average performance (513 vs. 505, see Figure 11, page 45). In physics, the results showed the United States AP Physics students to be below the international average (474 vs. 504, see Figure 17, page 52). In the administration of the TIMSS tests in 1995, AP students were identified by the school as being students who were taking, or had taken AP Calculus or AP Physics.

This report presents the results of a second administration of the TIMSS Advanced Mathematics test and TIMSS Physics test to a sample of students enrolled in AP Calculus and AP Physics courses throughout the United States. A total of 3819 students enrolled in AP Calculus AB or AP Calculus BC were administered the TIMSS Advanced Mathematics test. A total of 1869 students enrolled in AP Physics B or AP Physics C were administered the TIMSS Physics test.

In the TIMSS Advanced Mathematics test the AP Calculus students significantly outperformed all students in other countries in the TIMSS 1995 assessment except for students in France. Students who received a grade of 3 or above on the AP Calculus Exams performed even better. Although relatively small, there was a significant gender difference in the TIMSS Advanced Mathematics test that favored males enrolled in AP courses. A breakdown of the results by race/ethnicity showed that the majority of the AP students who took the TIMSS Advanced Mathematics test were White (72%) or Asian (21%) and that these two groups performed about the same. Other ethnic/race groups did not perform as well, but there were too few students to reliably report on their performance.

In the areas of Numbers and Equations and Calculus, the AP Calculus students also outperformed all other countries participating in TIMSS and performed significantly higher than the international average in Geometry. In the Advanced Mathematics content areas, gender differences were statistically significant for the AP students in the areas of Calculus and Geometry. These differences were smaller than the overall international gender differences in content areas.

In the TIMSS Physics test, the AP Physics students ranked 4th in performance behind Norway, Sweden and the Russian Federation, although students who received a grade of 3 or above on the AP Physics Exams performed better than these countries. Although relatively small, there was a significant gender difference in the TIMSS Physics test that favored males enrolled in AP courses. A breakdown of the results by race/ethnicity showed that the majority of the AP students who took the TIMSS Physics test were White (66%) or Asian (26%) and these two groups performed about the same. Other ethnic/race groups did not perform as well, but there were too few students to reliably report on their performance.

In the areas of Mechanics and Modern Physics, the AP Physics students performed significantly higher than the international average, while performing at the international average in Electricity and Magnetism, Heat, and Wave Phenomena. In the Physics content areas, gender differences were statistically significant for AP students in the areas of Mechanics, Electricity and Magnetism, and Wave Phenomena. However, only in Electricity and Magnetism was this difference greater than the international gender difference.

Introduction

The Goals 2000: Educate America Act stated that United States students would be first in the world in mathematics and science achievement by the year 2000. However, the Third International Mathematics and Science Study (TIMSS), the largest, most comprehensive, and most rigorous international study of student achievement ever undertaken, showed that United States twelfth-grade students in 1995 were, on average, not leading, but lagging behind the world in mathematics and science achievement. U.S. twelfth-graders ranked 16th among 21 countries in mathematics literacy and 16th among 21 countries in science literacy. Additionally, the United States students ranked last in physics achievement by the final year of secondary school and ranked second to last in advanced mathematics achievement when compared to students in other countries having taken similar courses of study.[1]

In the United States National TIMSS Report released in February 1998[2], data were presented comparing the average performance on the TIMSS Advanced Mathematics and Physics tests of final-year students having taken advanced mathematics or physics courses. In the U.S., the students sampled were classified as having taken advanced mathematics if they had taken at least

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[1] Mullis, I. V. S., Martin, M. O., Beaton, A. E., Gonzalez, E. J., Kelly, D. L., and Smith, T. A. (1998). *Mathematics and Science Achievement in the Final Year of Secondary School*: *IEA's Third International Mathematics and Science Study*, TIMSS International Study Center, Boston College, Chestnut Hill, MA: Boston College.

[2] U.S. Department of Education. National Center for Education Statistics, *Pursuing Excellence: A Study of U.S. Twelfth-Grade Mathematics and Science Achievement in International Context*, NCES98-049. Washington, DC: U.S. Government Printing Office, 1998.

one year of Pre-Calculus or Calculus[3], or had taken AP Calculus. U.S. students were classified as having taken physics if they had taken at least one year of physics or had taken AP Physics. The comparison of these students in the U.S. showed that advanced mathematics students and physics students were lagging behind other students around the world.

Additionally, the U.S. National TIMSS Report also presented the results of the comparison between the average performance of United States Advanced Placement Calculus students and advanced mathematics students from other countries and between Advanced Placement Physics students and physics students from other countries. The results in the United States National TIMSS Report showed the performance of AP Calculus students to be about mid-range among the 16 participating countries, and a little above the international average performance (513 vs. 505, see Figure 11, page 45). In physics, the results showed the United States AP Physics students to be below the international average (474 vs. 504, see Figure 17, page 52). In the administration of the TIMSS tests in 1995, AP students were identified by the school as students who were taking or had taken AP Calculus or AP Physics.

There have been questions raised about whether these results were an accurate indication of the performance on TIMSS of AP students nationwide. Various reasons have been cited for this, including the fact that some students enrolled in AP courses and classified as such do not actually complete those courses, some courses designated as AP courses do not actually follow the AP Course Description specified by the College Board for AP courses, and not all students enrolled in AP courses have attempted or passed the corresponding College Board AP Examinations (see Appendix A for a detailed description of the College Board's AP Calculus and Physics courses and examinations).

Different from the TIMSS test administration in 1995, this report presents the results of the administration of the TIMSS Advanced Mathematics and Physics tests in 2000, to a sample of 'certifiable' AP students who were enrolled in College Board AP courses. To select these students, AP courses were identified in schools registered with the College Board as having AP Calculus or Physics courses, and intact AP classes were selected for testing in these schools. The students selected were enrolled in the AP courses the year of testing. Many of these students also took the corresponding AP Exam at the end of the AP course. For these students, information was obtained about the AP Exam results. The results on the TIMSS test are reported for all students enrolled in AP courses and also separately for those students who obtained a "passing" AP Exam grade and for those students who did not. A student is considered to have passed an AP Exam if she or he receives an exam grade of 3 or above. These students are of particular interest in this study, since they are often awarded college credit and/or advanced placement on the basis of their AP Exam grade.

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[3] A student is classified as having taken the course if she or he had completed the course during the year previous to the TIMSS assessment year, or if she or he was taking the course during the assessment year.

The results of this study provide a reliable comparison of AP students at the end of the corresponding AP course against advanced mathematics and physics students around the world.

For the purpose of this report, we understand AP Calculus students to be those enrolled in an AP Calculus AB or AP Calculus BC course at the time of the TIMSS test administration during the school year 1999-2000. AP Physics students are those students enrolled in an AP Physics B or AP Physics C course at the time of the TIMSS test administration during the school year 1999-2000.

What is TIMSS?

TIMSS is the third international comparative study of mathematics achievement and the third international comparative study of science achievement carried out by the International Association for the Evaluation of Educational Achievement (IEA). Previous IEA studies of mathematics and science were conducted for each subject separately at various times during the 1960s, 1970s, and 1980s. TIMSS is the first IEA study that has assessed both mathematics and science at the same time.

TIMSS was designed to focus on students at three different stages of schooling: primary school years, middle school years, and at the end of upper secondary school. Initial findings for the 41 countries in the lower secondary school component, the 26 countries that participated in the elementary school component, and for the 23 countries that participated in the final years of schooling component have been reported in IEA publications[4], and the *Pursuing Excellence*[5] series within the United States.

TIMSS Assessments and Nature of this Report

The TIMSS assessments for the final years of secondary school were conducted in 1995 and focused on four areas of performance:

- Mathematics literacy for all students in the final year of secondary education, including those who had taken advanced mathematics and science courses;

- Science literacy for all students in the final year of secondary education, including those who had taken advanced mathematics and science courses;

- Advanced mathematics for students in the final year of secondary education who had taken or were taking advanced courses in mathematics;

- Physics for students in the final year of secondary education who had taken or were taking at least one year of physics.

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[4] The IEA TIMSS publications are listed in Appendix C and are available on the internet: http://isc.bc.edu.

[5] Available for downloading at http://nces.ed.gov/timss/.

The TIMSS Advanced Mathematics test for final year students was designed to enable reporting by three content areas as well as for advanced mathematics overall. The advanced mathematics content areas are:

- Numbers and Equations: Complex numbers and their properties; permutations and combinations; equations and formulas; and patterns, relations, and functions;

- Calculus: Infinite processes; and change;

- Geometry: Basic geometry; coordinate geometry; polygons and circles; and three-dimensional geometry.

The TIMSS Physics test for final year students was designed to enable reporting by five content areas as well as for physics overall. The physics content areas are:

- Mechanics: Dynamics of motion; time, space and motion; types of forces; and fluid behavior;

- Electricity and Magnetism: Electricity; and magnetism;

- Heat: Physical changes; energy types, sources and conversions; heat and temperature; and kinetic theory;

- Wave Phenomena: Sound and vibration; light; and wave phenomena;

- Modern physics: Nuclear chemistry; quantum theory and fundamental particles; astrophysics; subatomic particles; and relativity theory.

This report presents achievement on the TIMSS Advanced Mathematics and TIMSS Physics tests, of United States students enrolled in AP courses, compared with achievement in 1995 of physics and advanced mathematics students in 18 countries: Australia, Austria, Canada, Cyprus, the Czech Republic, Denmark, France, Germany, Greece, Italy, Latvia, Lithuania, Norway, the Russian Federation, Slovenia, Sweden, Switzerland, and the United States. Italy and Lithuania administered only the advanced mathematics test, while Latvia and Norway administered only the physics test.

Design and Methodology

For a valid comparison, it was very important that this re-administration of the TIMSS Advanced Mathematics and TIMSS Physics tests was implemented with a representative sample of AP Calculus and AP Physics students and for the study to follow the procedures implemented when the tests were administered in 1995. To this effect, most field operations, including scoring and data entry, were conducted by the same contractor that conducted the original assessment, using identical data collection instruments and methodologies.

Students Tested

Schools were sampled from a list of 9347 schools located in the 50 United States offering AP Calculus or AP Physics courses during the 1999 - 2000 school year. A sample of 395 schools was selected from this group with probability proportional to the number of students passing any of the AP Calculus or AP Physics exams in 1999. Of the 395 schools selected, 387 had students who had taken AP Calculus exams in 1999 and 334 had students who had taken AP Physics Exams in 1999.

Of the sampled schools, only 104 agreed to participate despite numerous attempts to secure participation. Of these 104 schools, 97 had students enrolled in AP Calculus courses and 68 had students enrolled in AP Physics courses. In each school, intact AP Calculus classes and intact AP Physics classes were tested when available. A total of 3819 students were administered the TIMSS Advanced Mathematics test and 1869 students were administered the TIMSS Physics test. In some cases the same students took both tests when they were enrolled in both courses. Students were tested regardless of grade.

After data collection was completed the results from the AP Calculus and AP Physics Exams were matched to the individual student records for the corresponding TIMSS test. A summary of these results is presented in Exhibit 1:

Exhibit 1: Students Taking and Passing the AP Calculus and AP Physics Exams

AP Exam Type	Students Taking the Exam	Received AP Exam Grade of 3 or Better*
AP Calculus AB	1687	1372
AP Calculus BC	676	615
AP Physics B	568	405
AP Physics C (E+M)	180	150
AP Physics C (M)	321	258

* An AP Exam grade of 3 or better indicates a passing score.

Test Administration

Students were tested May through July of 2000. Boston College staff was responsible for overseeing the preparation and shipment of testing materials and manuals to the test administrators. The TIMSS tests were administered by the AP test administrators in the schools. Boston College staff took responsibility for contacting the test administrators, providing the test administrators with testing dates and locations, and preparing them for conducting the testing. The test administrators received no formal training but were provided with a detailed manual regarding preparation and test administration procedures. Since these individuals are experienced in test administration, they were able to conduct the administration as prescribed in the manual. National Computing Systems (NCS) was contracted to ship all testing materials directly to the test administrator prior to the testing date and served as the contact to respond to any inquiries from the test administrators. NCS also received the material back from the field, scored the open-ended items and conducted the data entry.

Quality Control

To ensure the proper implementation of the TIMSS policies and procedures in the schools and during test administration, Boston College conducted quality control site visits to a sample of the tested schools. Fifteen schools administering the TIMSS Advanced Mathematics and 15 schools administering the TIMSS Physics tests were visited by the Quality Control Monitors.

Quality Control Monitors were trained in a one-day session during which they were briefed on the design and purpose of the testing, the responsibilities of the data collection staff, and their own roles and responsibilities. Where possible, experienced TIMSS-R Quality Control Monitors were hired to conduct the site visits.

Each quality control monitor was provided with procedural manuals for the AP Study based on the TIMSS Manual for International Quality Control Monitors. This manual details monitoring procedures. Each Quality Control Monitor prepared a report documenting their findings. In summary, the QCM reported that the procedures during testing administration were followed as specified in the corresponding manuals.

Scoring Student Responses

Approximately one-third of the TIMSS testing time is devoted to open-ended questions where students are asked to construct their own responses. These items are scored using two-digit codes with rubrics specific to each item. The first digit designates the correctness level of the response. The second digit, combined with the first, represents a diagnostic code used to identify specific types of approaches, strategies, or common errors and misconceptions. The scoring was conducted by NCS, using the scorers from the same pool of professional scorers used to score the 1995 United States TIMSS data. The scoring of the responses started with a training session conducted by the same trainers who conducted the training session in 1995.

Database Construction and Data Entry

Subsequent to the scoring, NCS conducted data entry and database construction according to the same procedures used to create the database in 1995. Staff at Boston College engaged in a careful cleaning process to identify, document, and correct any deviation from the international database structure and coding scheme. This process also emphasized the consistency of the information within the data sets.

At this time, sampling weights were calculated and added to the files. Because of the relatively low participation rate at the school level, individual student sampling weights were calculated such that the contribution of each school to the overall estimate was the same. Schools were assigned in pairs to sampling zones for the purpose of computing standard errors and confidence intervals for significance testing.

Scaling

Boston College worked with the Australian Council for Educational Research (ACER) to conduct the scaling and computation of scores on the TIMSS tests. The TIMSS achievement data are summarized using an item response theory (IRT) scaling method. This scaling method produces scores by combining the responses of each student to the items that she or he took in a way that takes into account the difficulty of each item. The methodology used in TIMSS includes refinements that enable reliable scores to be produced even though individual students respond to relatively small subsets of the total pool of items. The methodology also provides comparable estimates of performance for all students, even though they answer different test items depending upon which of the test booklets they receive.

The TIMSS Advanced Mathematics test contains a total of 65 items distributed across three forms, each containing 28 or 29 test items. An overall mathematics score was calculated for each student who took the TIMSS Advanced Mathematics test. Additionally, scores were also computed to summarize the performance of the students on the items covering the content areas of Numbers, Equations, and Functions; Calculus; and Geometry.

The TIMSS Physics test also contains 65 items distributed across three forms, each containing 27 or 29 items. An overall physics score was calculated for each student who took the TIMSS Physics test. Additionally, scores were also computed to summarize the performance of the students on items covering the content areas of Mechanics; Electricity and Magnetism; Heat; Wave Phenomena; and Modern Physics.

Following procedures used in 1995, each student was given one form of the advanced mathematics or physics test, as appropriate, and allowed 90 minutes to respond to the items. ACER conducted the scaling of the data collected from the AP Calculus and AP Physics students using the same software and item parameters used to scale the TIMSS data in 1995. Scores could range from 5 to 995 with an international average scale score of 500.

What Was the Nature of the TIMSS 1995 Physics and Advanced Mathematics Samples?

The TIMSS 1995 advanced mathematics and physics study was designed to provide information about how well-prepared the population of school-leaving students that has taken advanced mathematics or physics is to pursue higher education or occupations in mathematics or science. In all countries, the students participating in the advanced mathematics or physics testing had taken courses in advanced mathematics or physics and were in the final year of secondary school at the time of testing. However, the exact definition of the population varied across countries in terms of which courses and how much advanced mathematics or physics the students had taken at the time of testing (see Mullis et al., 1998 Appendix A for more details).

The percentage of the student population who took the advanced tests varied from country to country. To address this issue, TIMSS developed the Mathematics TIMSS Coverage Index (MTCI) and the Physics TIMSS Coverage Index (PTCI). These are estimates of the percentage of a country's school-leaving age cohort that has taken advanced mathematics or physics who were selected to take the TIMSS tests. These indices are indicators of the selectivity of the country's mathematics or physics students. Exhibit 2 shows that in most of the TIMSS countries, advanced mathematics and physics are taken by only a small proportion of students in upper secondary school.

The Mathematics TIMSS Coverage Index (MTCI) reflects the percentage of the entire school-leaving age cohort covered by the student sample for the advanced mathematics testing. The MTCI shows the differing levels of overall sample coverage of this cohort in each country, including omissions of students who have left the educational system (e.g., by dropping out) and sampling exclusions. In addition, the MTCI shows that a relatively small subset of final-year students in each country have taken the advanced mathematics courses necessary to participate in this portion of the testing, and that the percentage of these students varies across countries. In general, most participating countries tested 20% or less of their school-leaving age cohort in advanced mathematics. Exceptions were Austria, Germany and Slovenia.

The MTCI was very low in Lithuania (3%) and the Russian Federation (2%). In contrast 75% of the school-leaving cohort in Slovenia takes advanced mathematics and were part of the sampled students. A number countries had an MTCI about the same as the United States (14%). These countries include Switzerland, Australia, Italy, Sweden, the Czech Republic, and Canada.

The Physics TIMSS Coverage Index (PTCI) reflects the percentage of the entire school-leaving age cohort covered by the student samples for the physics testing. Like the MTCI, the PTCI shows that a relatively small subset of the final-year students in each country have taken the physics courses necessary to participate in this portion of the testing, and that the percentage of these students varies across countries.

The PTCI was low in Norway (8%), and particularly low in Denmark (3%), Latvia (3%), and the Russian Federation (2%) indicating that physics students in these countries are a very select group. In contrast, in Slovenia and in Austria, about one third of the school-leaving age cohort takes physics and were part of the sampled students. A number of countries had PTCI's about the same as the United States (14%). These countries include Australia, Canada, Czech Republic, France, Sweden, and Switzerland.

Exhibit 2: TIMSS Coverage Indices (TCIs) for Advanced Mathematics and Physics

	Mathematics TIMSS Coverage Index (MTCI)*	Physics TIMSS Coverage Index (PTCI)†
Australia	15.7%	12.6%
Austria	33.3%	33.1%
Canada	15.6%	13.7%
Cyprus	8.8%	8.8%
Czech Republic	11.0%	11.0%
Denmark	20.6%	3.2%
France	19.9%	19.9%
Germany	26.3%	8.4%
Greece [1]	10.0%	10.0%
Italy	14.1%	–
Latvia [3]	–	3.0%
Lithuania	2.6%	–
Norway	–	8.4%
Russian Federation	2.0%	1.5%
Slovenia	75.4%	38.6%
Sweden	16.2%	16.3%
Switzerland	14.3%	14.2%
United States	13.7%	14.5%

* MTCI: Estimated percentage of school-leaving age cohort covered by TIMSS sample of advanced mathematics students.

† PTCI: Estimated percentage of school-leaving age cohort covered by TIMSS sample of physics students.

1 Greece sampled only students having taken advanced mathematics and physics.

2 Latvia sampled only students having taken physics.

Note: Norway and Latvia did not participate in the advanced mathematics testing and Italy and Lithuania did not participate in the physics testing.

Student Achievement in Advanced Mathematics

How Does Advanced Mathematics Performance of Advanced Placement Students Compare With Students Internationally?

Exhibit 3 presents the average achievement in advanced mathematics for 16 countries, including the United States and the AP Calculus students tested in 2000. Countries[1] with triangles pointing up next to their average achievement performed significantly above the international average scale score of 501. The highest performing students were AP Calculus students having a scale score average of 573. Others performing significantly above the international average include the AP Calculus students, France, the Russian Federation, Switzerland, Cyprus, Lithuania, and Denmark. Countries with triangles pointing down had average achievement significantly below the international average. The United States belongs in this group with a scale score average of 442. Others performing significantly below the international average include the Czech Republic, Germany, and Austria.

In contrast to these results, the NCES 1998 report, *Pursuing Excellence,* indicates that “the performance of U.S. twelfth graders with Advanced Placement calculus instruction, who represent about 5 percent of the United States age cohort, was significantly higher than the performance of advanced mathematics students in 5 other countries”.[2] This report shows the AP Calculus students with an average achievement of 513 on the TIMSS Advanced Mathematics test.

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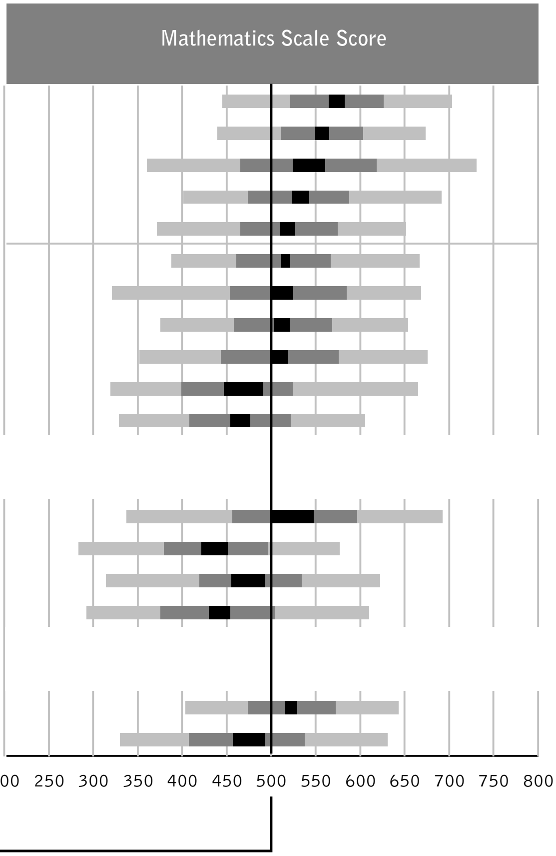
[1] AP students will be referred to as a ‘country’ for ease of discussion.

[2] U.S. Department of Education. National Center for Education Statistics, *Pursuing Excellence: A Study of U.S. Twelfth-Grade Mathematics and Science Achievement in International Context,* NCES98-049. Washington, DC: U.S. Government Printing Office, 1998.

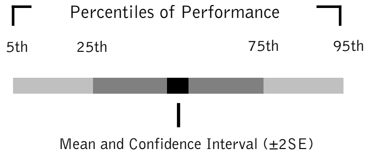
Exhibit 3: Distribution of Advanced Mathematics Achievement for Students Having Taken Advanced Mathematics – Final Year of Secondary School*

Country	Average Achievement	MTCI‡	Average Age
■ AP Calculus Students	▲ 573 (4.4)		18.0
France	▲ 557 (3.9)	20%	18.2
[2] Russian Federation	▲ 542 (9.2)	2%	16.9
Switzerland	▲ 533 (5.0)	14%	19.5
[2] Cyprus	▲ 518 (4.3)	9%	17.7
[1‡] Lithuania	▲ 516 (2.6)	3%	17.9
[†] Greece	● 513 (6.0)	10%	17.7
Sweden	● 512 (4.4)	16%	18.9
Canada	● 509 (4.3)	16%	18.5
Czech Republic	▼ 469 (11.2)	11%	18.1
[†] Germany	▼ 465 (5.6)	26%	19.2
Countries Not Satisfying Guidelines for Sample Participation Rates			
Australia	● 525 (11.6)	16%	17.8
[2] Austria	▼ 436 (7.2)	33%	19.1
[1] Italy	● 474 (9.6)	14%	19.1
United States	▼ 442 (5.9)	14%	18.0
Countries With Unapproved Sampling Procedures and Low Participation Rates			
Denmark	▲ 522 (3.4)	21%	19.2
Slovenia	● 475 (9.2)	75%	18.9



International Average = 501 (1.8)
Average of all country means

- ▲ Country mean significantly higher than international mean
- ▼ Country mean significantly lower than international mean
- ● No statistically significant difference between country mean and international mean



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* See Mullis and others, 1998 Appendix A for characteristics of the students sampled.

‡ The Mathematics Test Coverage Index (MTCI) is an estimate of the percentage of the school-leaving age cohort covered by the TIMSS final-year mathematics student sample (see Mullis and others, 1998 Appendix B for more information).

† Met guidelines for sample participation rates only after replacement schools were included (see Mullis and others, 1998 Appendix B for details).

1 National Desired Population does not cover all of International Desired Population (see Mullis and others, 1998 Table B.4).

2 National Defined Population covers less than 90 percent of National Desired Population (see Mullis and others, 1998 Table B.4).

( ) Standard errors appear in parentheses. Because results are rounded to the nearest whole number, some totals may appear inconsistent.

The upper part of the exhibit shows, in decreasing order of average achievement, the 10 countries judged to have met the TIMSS requirements for testing a representative sample of the students having taken advanced mathematics in accordance with their national definitions. While some countries had more success in locating these advanced students and encouraging participation in the testing than they had for the entire school-leaving population, others encountered resistance from schools and students and failed to reach the overall participation rates of 75% or higher (for schools and students combined) specified in the TIMSS guidelines (i.e., Australia, Austria, Italy, and the United States). Denmark and Slovenia also had some difficulties in implementing the prescribed sampling methods and as a consequence are reported in separate panels. Because the AP Calculus students represent the group of interest for this report, their results are presented in the top panel of the exhibits together with countries that met the overall participation rates, even though the sample had a low response rate.

The average age of students gives some idea of the years of formal schooling in the participating countries. Nevertheless, because of different policies regarding the age for starting school and for retention, students of similar ages have not necessarily had the same number of years of formal schooling.

The results in Exhibit 3, especially the visual representations of the performance distributions within each country, suggest some similarity in average performance among many of the countries, although there is variation from the top- to the bottom-performing ones. For instance, the AP Calculus students performed very similar to students in France while varying considerably from the performance of the United States. In contrast to the overlapping performance across a number of the countries in their average achievement (shown by the dark boxes at the distribution midpoints representing the 95% confidence intervals around the means), the range in within-country performance usually was substantial (shown by the 5th and 95th percentiles, representing the extremes of lower and higher achievement). When comparing the performance of the AP Calculus students to the United States students, the AP Calculus students scoring at the lowest level of achievement are performing at the mean of the United States students. Complementing this information, the percentiles and standard deviations of achievement at the 5th, 25th, 50th, 75th, and 95th percentiles for each country and the AP Calculus students are presented in Exhibit B.1 in Appendix B.

Exhibit 4 also compares countries in terms of average achievement in advanced mathematics. It shows whether or not the differences in average achievement between pairs of countries are statistically significant.[3] Selecting a country of

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[3] The significant tests in Exhibit 4 are based on a Bonferroni procedure for multiple comparisons that holds to 5% the probability of erroneously declaring the mean of one country to be different from that of another country.

Exhibit 4: Multiple Comparisons of Advanced Mathematics Achievement for Students Having Taken Advanced Mathematics – Final Year of Secondary School*

Instructions: Read ***across*** the row for a country to compare performance with the countries listed in the heading of the chart. The symbols indicate whether the mean achievement of the country in the row is significantly lower than that of the comparison country, significantly higher than that of the comparison country, or if there is no statistically significant difference between the two countries.‡

	AP Calculus Students	France	Russian Federation	Switzerland	*Australia*	*Denmark*	Cyprus	Lithuania	Greece	Sweden	Canada	*Slovenia*	*Italy*	Czech Republic	Germany	*United States*	*Austria*
AP Calculus Students		●	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
France	●		●	▲	●	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
Russian Federation	▼	●		●	●	●	●	●	●	▲	▲	▲	▲	▲	▲	▲	▲
Switzerland	▼	▼	●		●	●	●	▲	●	▲	▲	▲	▲	▲	▲	▲	▲
Australia	▼	●	●	●		●	●	●	●	●	●	▲	▲	▲	▲	▲	▲
Denmark	▼	▼	●	●	●		●	●	●	●	●	▲	▲	▲	▲	▲	▲
Cyprus	▼	▼	●	●	●	●		●	●	●	●	▲	▲	▲	▲	▲	▲
Lithuania	▼	▼	●	▼	●	●	●		●	●	●	▲	▲	▲	▲	▲	▲
Greece	▼	▼	●	●	●	●	●	●		●	●	▲	▲	▲	▲	▲	▲
Sweden	▼	▼	▼	▼	●	●	●	●	●		●	▲	▲	▲	▲	▲	▲
Canada	▼	▼	▼	▼	●	●	●	●	●	●		▲	▲	▲	▲	▲	▲
Slovenia	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼		●	●	●	▲	▲
Italy	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	●		●	●	●	▲
Czech Republic	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	●	●		●	●	●
Germany	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	●	●	●		●	▲
United States	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	●	●	●		●
Austria	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	●	▼	●	

Countries are ordered by average achievement across the heading and down the rows.

▲	Mean achievement significantly higher than comparison country	●	No statistically significant difference from comparison country	▼	Mean achievement significantly lower than comparison country

* See Mullis and others, 1998 Appendix A for characteristics of the students sampled.

‡ Statistically significant at .05 level, adjusted for multiple comparisons.

Countries shown in italics did not satisfy one or more guidelines for sample participation rates or student sampling (see Mullis and others, 1998 Figure B.6).

interest and reading across the exhibit, a triangle pointing up indicates significantly higher performance than the country listed across the top, a dot indicates no significant difference in performance, and a triangle pointing down indicates significantly lower performance.

The exhibit shows that AP Calculus students significantly outperformed all countries except France. There were essentially two groupings of countries by average performance. The top group led by the AP Calculus students, also included France, the Russian Federation, Switzerland, Australia, Denmark, Cyprus, Lithuania, Greece, Sweden, and Canada. Among these countries, the Russian Federation (2%) and Lithuania (3%) tested a rather small percentage of their school-leaving age cohort in advanced mathematics, and Australia and Denmark did not meet the TIMSS sampling guidelines. The second group of countries included Slovenia, Italy, the Czech Republic, Germany, the United States, and Austria. Here it should be noted that Slovenia tested three-fourths of its school-leaving age cohort, and Austria (33%) also had a comparatively higher MTCI than the other participants, as did Germany (26%).

How Do Students Who Pass the AP Calculus Exam Perform on the TIMSS Advanced Mathematics Test?

A student is considered to have passed the AP Calculus Exam if she or he obtains an AP Exam grade of 3 or above. Exhibit 5 shows the average achievement of AP Calculus students receiving this passing score compared with those AP Calculus students scoring below 3. Students could choose to take the AP Calculus AB or AP Calculus BC exam. For both of the AP Calculus Examinations, students receiving a grade of 3 or above performed better on the TIMSS Advanced Mathematics test than those who did not. Students who received a grade of 3 or above on the AP Calculus AB Exam had an average scale score of 586, while those receiving a grade of less than 3 had an average scale score of 565, for a difference of 21 scale score points. A much larger difference of 69 scale score points is seen in the students who took the Calculus BC Exam. AP Calculus students receiving a grade of 3 or above on the AP Calculus BC Exam scored an average scale score of 633, while those receiving a grade of less than 3 had an average scale score of 564. Furthermore, students who obtained a grade of 3 or above on either of the AP Calculus Exams obtained an average score of 596 (3.2) on the TIMSS Advanced Mathematics test, outperforming all other countries.

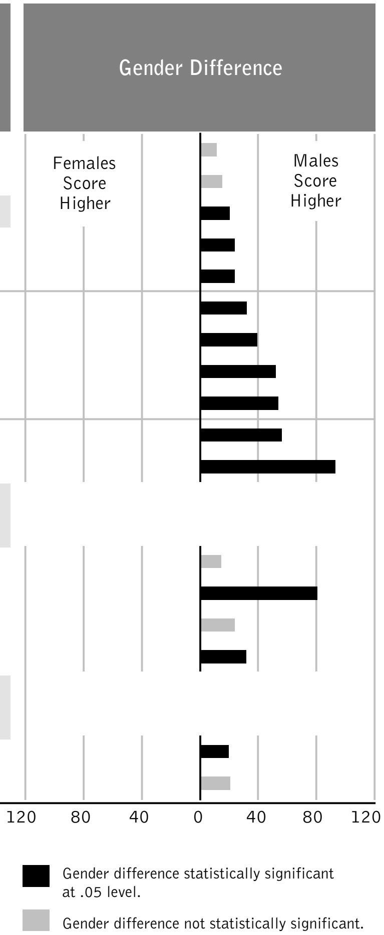
Exhibit 5: Average Achievement of AP Calculus Students in Advanced Mathematics by Results AP Calculus Examinations

Score on AP Calculus Exam	Average Achievement
Less than 3 on AP Calculus AB	565 (6.6)
3 or better on AP Calculus AB	586 (3.5)
Less than 3 on AP Calculus BC	564 (4.6)
3 or better on AP Calculus BC	633 (5.8)

( ) Standard errors appear in parentheses.

Exhibit 6: Gender Differences in Advanced Mathematics Achievement for Students Having Taken Advanced Mathematics – Final Year of Secondary School*

Country	Males		Females		Difference	MTCI
	Percent of Students	Average Achievement	Percent of Students	Average Achievement		
† Greece	69 (2.1)	516 (6.6)	31 (2.1)	505 (10.2)	11 (12.1)	10%
2 Cyprus	61 (1.6)	524 (4.4)	39 (1.6)	509 (6.4)	15 (7.8)	9%
■ AP Calculus Students	58 (2.0)	581 (5.9)	42 (2.0)	562 (3.8)	20 (7.1)	
France	63 (2.0)	567 (5.1)	37 (2.0)	543 (5.1)	23 (7.2)	20%
Sweden	69 (3.4)	519 (5.9)	31 (3.4)	496 (5.2)	23 (7.9)	16%
† Germany	43 (2.4)	484 (6.5)	57 (2.4)	452 (6.6)	32 (9.2)	26%
Canada	53 (1.6)	528 (6.4)	47 (1.6)	489 (4.4)	39 (7.7)	16%
1‡ Lithuania	51 (1.9)	542 (3.7)	49 (1.9)	490 (5.6)	51 (6.7)	3%
2 Russian Federation	52 (2.4)	568 (9.7)	48 (2.4)	515 (10.2)	53 (14.1)	2%
Switzerland	54 (2.4)	559 (5.6)	46 (2.4)	503 (5.7)	56 (8.0)	14%
Czech Republic	41 (2.5)	524 (13.0)	59 (2.5)	432 (8.9)	92 (15.7)	11%
Countries Not Satisfying Guidelines for Sample Participation Rates						
Australia	55 (5.5)	531 (11.4)	45 (5.5)	517 (15.1)	14 (18.9)	16%
2 Austria	38 (4.1)	486 (7.3)	62 (4.1)	406 (8.6)	80 (11.2)	33%
1 Italy	61 (3.8)	484 (10.6)	39 (3.8)	460 (14.1)	24 (17.7)	14%
United States	51 (2.6)	457 (7.8)	49 (2.6)	426 (7.1)	31 (10.5)	14%
Countries With Unapproved Sampling Procedures and Low Participation Rates						
Denmark	63 (1.8)	529 (4.4)	37 (1.8)	510 (4.6)	19 (6.3)	21%
Slovenia	50 (4.2)	484 (11.5)	50 (4.2)	464 (11.0)	20 (15.9)	75%



International Averages		
Males	Females	Difference
519	482	37

(Average of all country means)

* See Mullis and others, 1998 Appendix A for characteristics of the students sampled.

† Met guidelines for sample participation rates only after replacement schools were included (see Mullis and others, 1998 Appendix B for details).

1 National Desired Population does not cover all of International Desired Population (see Mullis and others, 1998 Table B.4).

2 National Defined Population covers less than 90 percent of National Desired Population (see Mullis and others, 1998 Table B.4).

( ) Standard errors appear in parentheses. Because results are rounded to the nearest whole number, some differences may appear inconsistent.

How Does Performance in Advanced Mathematics Compare by Gender and Race/Ethnicity?

Exhibit 6 presents differences in achievement by gender. The exhibit shows average achievement in advanced mathematics separately for males and females for each country, as well as the difference between the averages. The graphic representation of the gender difference, shown by the bar for each country, shows that the direction of the difference favored males in every country, and that the difference usually was statistically significant as indicated by a darkened bar. The AP Calculus students showed a statistically significant gender difference of 20 scale score points, favoring males. This difference was less than the United States gender difference of 31 scale score points which also favored males. There was a larger gender difference internationally (international average difference of 37 scale score points), and especially large differences were found in the Czech Republic and Austria (80 points or more). The gender differences were not statistically significant in Greece, Cyprus, Australia, Italy, and Slovenia.

Exhibit 6 also shows the percentage of upper secondary school students who have taken advanced mathematics courses by gender. The results reveal that many more (at least 20%) males than females have taken advanced mathematics in Greece, Cyprus, Sweden, France, Italy, and Denmark. More males than females have also taken advanced mathematics in several other countries, although the differences are not as large (AP Calculus students 16%, Australia 10%, Switzerland 8%, and Canada 6%). The percentages of males and females taking advanced mathematics are nearly identical in Lithuania, the Russian Federation, the United States, and Slovenia. In contrast, more females than males have taken advanced mathematics courses in three of the participating countries – Germany (14%), the Czech Republic (18%) and Austria (24%). Standard deviations of achievement in advanced mathematics by gender are presented in Exhibit B.2 in Appendix B.

Exhibit 7 shows the TIMSS advanced mathematics results for the AP Calculus students by race/ethnicity. The sample selected was predominantly White (Not Hispanic) with 72% of students identifying themselves with this group. The average scale score for White (Not Hispanic) students was 574. The next largest group was Asian or Pacific Islander with 21% of the sampled students. The average scale score for Asian or Pacific Islander was 578. Hispanic and Other students

Exhibit 7: Average Achievement Of AP Calculus Students in Advanced Mathematics by Students' Race/Ethnicity

Race/Ethnicity	Percent of Students	Average Achievement
White (Not Hispanic)	72 (2.8)	574 (4.4)
Black (Not Hispanic)	1 (0.3)	~ ~
[1] Hispanic	3 (0.9)	533 (46.8)
[2] Asian or Pacific Islander	21 (2.4)	578 (9.2)
[3] American Indian or Alaskan Native	0 (0.1)	~ ~
Other	4 (0.5)	568 (8.8)

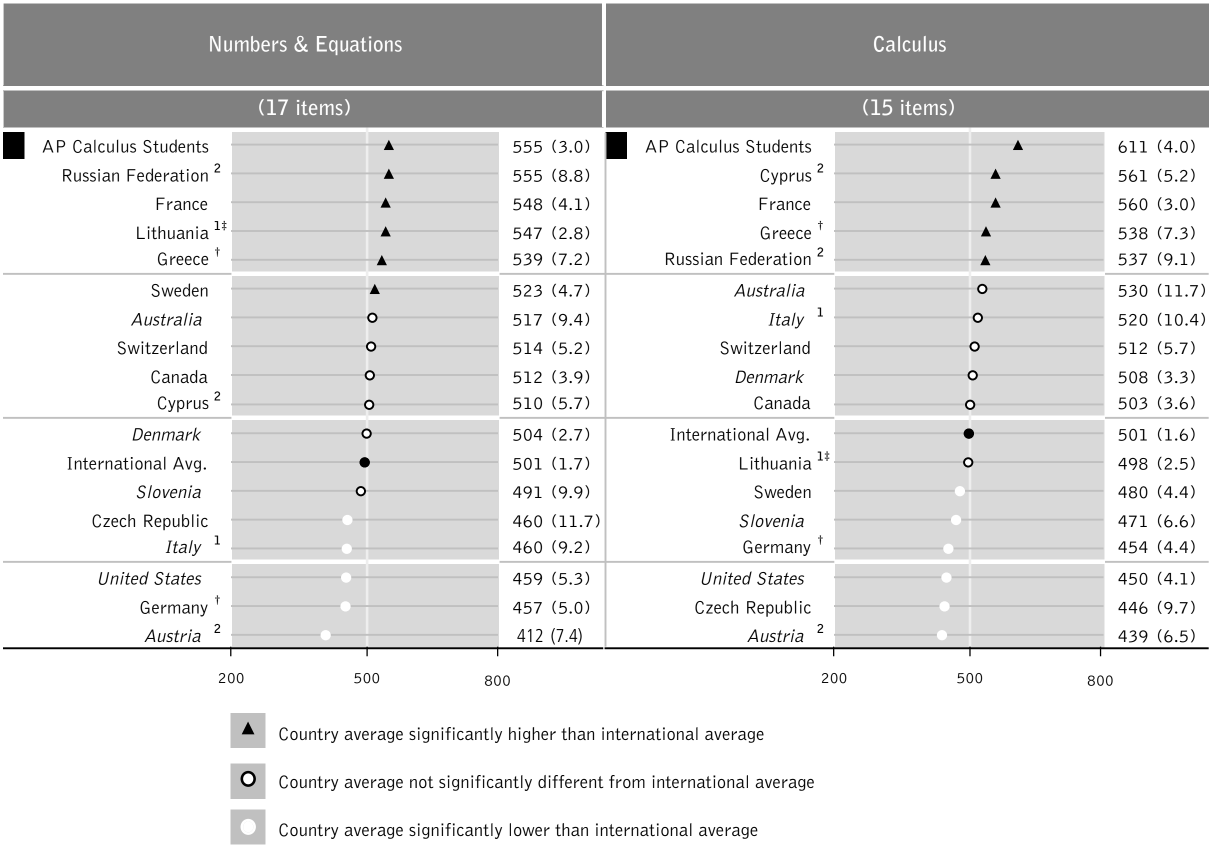
1 "Hispanic" means someone who is Mexican, Mexican American, Chicano, Puerto Rican, Cuban, or from some other Spanish or Hispanic background.

2 "Asian or Pacific Islander" means someone who is Chinese, Japanese, Korean, Filipino, Vietnamese, Asian American, or from some other Asian or Pacific Island background.

3 "American Indian or Alaskan Native" means someone who is from one of the American Indian tribes, or from one of the original people of Alaska.

( ) Standard errors appear in parentheses.

Exhibit 8: Average Achievement in Advanced Mathematics Content Areas for Students Having Taken Advanced Mathematics – Final Year of Secondary School*



Numbers & Equations (17 items)			Calculus (15 items)		
AP Calculus Students	▲	555 (3.0)	AP Calculus Students	▲	611 (4.0)
Russian Federation 2	▲	555 (8.8)	Cyprus 2	▲	561 (5.2)
France	▲	548 (4.1)	France	▲	560 (3.0)
Lithuania 1‡	▲	547 (2.8)	Greece †	▲	538 (7.3)
Greece †	▲	539 (7.2)	Russian Federation 2	▲	537 (9.1)
Sweden	▲	523 (4.7)	*Australia*	○	530 (11.7)
Australia	○	517 (9.4)	*Italy* 1	○	520 (10.4)
Switzerland	○	514 (5.2)	Switzerland	○	512 (5.7)
Canada	○	512 (3.9)	*Denmark*	○	508 (3.3)
Cyprus 2	○	510 (5.7)	Canada	○	503 (3.6)
Denmark	○	504 (2.7)	International Avg.	●	501 (1.6)
International Avg.	●	501 (1.7)	Lithuania 1‡	○	498 (2.5)
Slovenia	○	491 (9.9)	Sweden	◦	480 (4.4)
Czech Republic	◦	460 (11.7)	*Slovenia*	◦	471 (6.6)
Italy 1	◦	460 (9.2)	Germany †	◦	454 (4.4)
United States	◦	459 (5.3)	*United States*	◦	450 (4.1)
Germany †	◦	457 (5.0)	Czech Republic	◦	446 (9.7)
Austria 2	◦	412 (7.4)	*Austria* 2	◦	439 (6.5)

▲ Country average significantly higher than international average

○ Country average not significantly different from international average

◦ Country average significantly lower than international average

* See Mullis and others, 1998 Appendix A for characteristics of the students sampled.

† Met guidelines for sample participation rates only after replacement schools were included (see Mullis and others, 1998 Appendix B for details).

1 National Desired Population does not cover all of International Desired Population (see Mullis and others, 1998 Table B.4).

2 National Defined Population covers less than 90 percent of National Desired Population (see Mullis and others, 1998 Table B.4).

( ) Standard errors appear in parentheses. Because results are rounded to the nearest whole number, some differences may appear inconsistent.

Countries shown in italics did not satisfy one or more guidelines for sample participation rates or student sampling (see Mullis and others, 1998 Figure B.6)

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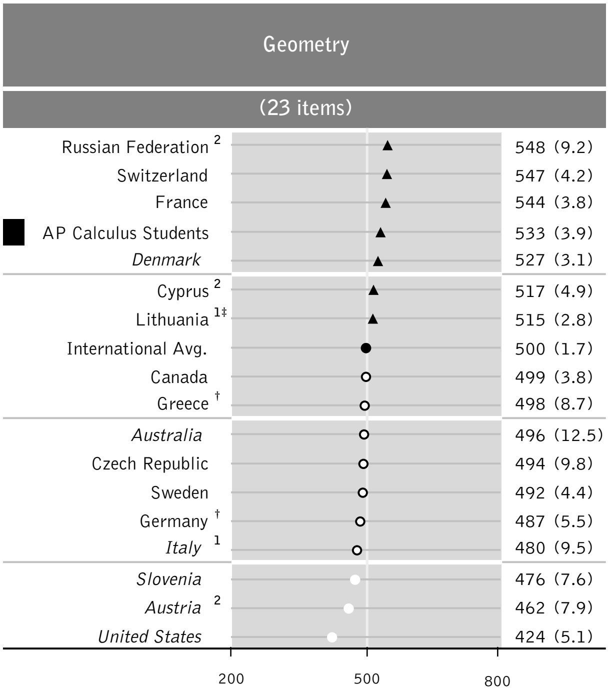
made up approximately 3% and 4% of the sample, respectively. The average scale score for Hispanic students was 533, while Other students scored 568. Due to the low percentage of Black (Not Hispanic) students and American Indian or Alaskan Native students in the sample, their achievement data is not presented.

Exhibit 8
(Continued)



How Does Advanced Mathematics Performance Compare Across Content Areas?

Recognizing that important curricular differences exist between and within countries is an important aspect of IEA studies, and TIMSS sought to measure achievement in different areas of advanced mathematics, which would be useful in relating achievement to curriculum. The TIMSS Advanced Mathematics test was designed to enable reporting by three content areas.[4] These three content areas are:

- Numbers, equations, and functions
- Calculus
- Geometry

The advanced mathematics test also included several items dealing with probability and statistics and several in the area of validation and structure. The results for these items were included in the scaling of the overall results, but there were too few items in these two categories to develop separate sub-scales.[5] Given that the test was designed to include items from different curricular areas, it is important to examine whether the participating countries have particular strengths and weaknesses in their achievement in these areas.

Exhibit 8 presents the sub-scale scores for the three major content areas in the advanced mathematics test. As indicated earlier, the international averages for each of the sub-scales were arbitrarily set to be 500 with a standard deviation of 100.[6] Countries that did well on the overall advanced mathematics test sometimes did well in the three content areas, and those that did poorly overall also tended to do so in each of the content areas.

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[4] See the "Test Development" section of Appendix B in Mullis, I.V.S., Martin, M.O., Beaton, A.E., Gonzales, E.J., Kelly, D.L., and Smith,.T.A. (1998), *Mathematics and Science Achievement in the Final Year of Secondary School: IEA's Third International Mathematics and Science Study*, Chestnut Hill, MA: Boston College.

[5] See the "IRT Scaling and Data Analysis" section of Appendix B in Mullis, I.V.S., Martin, M.O., Beaton, A.E., Gonzales, E.J., Kelly, D.L., and Smith,T.A. (1998), *Mathematics and Science Achievement in the Final Year of Secondary School: IEA's Third International Mathematics and Science Study*, Chestnut Hill: Boston College.

[6] Final revisions of the data resulted in international averages of 501 for some of the advanced mathematics scales.

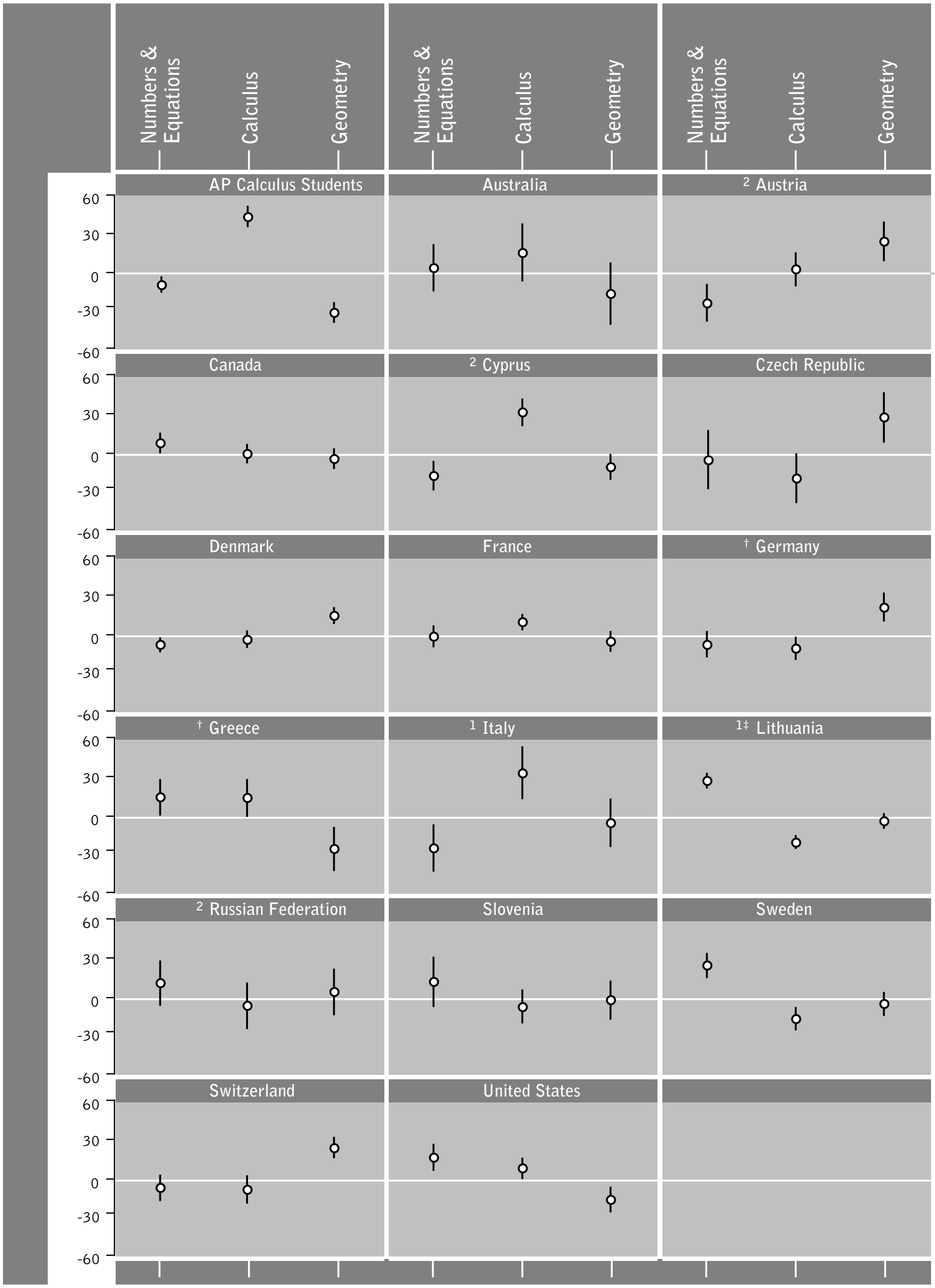
The AP Calculus students, who performed above the international average in advanced mathematics overall, also performed above the international average in each of the three content areas. In Numbers and Equations, and in Calculus, AP Calculus students ranked first. The United States students, who performed below the international average in advanced mathematics overall, also performed below the international average in each of the content areas. The United States ranked third from the last in Numbers and Equations, and Calculus, and ranked last in Geometry. Most countries, however, showed particular strengths or weaknesses. Sweden performed above the international average in Numbers and Equations, below the international average in Calculus, and about at the international average in Geometry. Switzerland performed above the international average in Geometry, but only at the international average in Numbers and Equations and in Calculus.

Exhibit 9 presents a visual profile of performance in the advanced mathematics content areas in each country. In this profile, the comparison is with the country's overall average achievement, so that regardless of the performance of the country relative to that of other participants, particular strengths and weaknesses within the country can be identified. The horizontal line represents each country's overall average achievement in the three advanced mathematics content areas, and the vertical lines indicate the 95% confidence intervals around the average achievement (hollow circle) in each of the three major content areas. If the hollow circle and corresponding 95% confidence interval is below the line, then the country performed significantly lower in that content area than it did overall. Similarly, if the hollow circle and corresponding 95% confidence interval is above the line, then the country performed significantly better in that content area than it did overall.

The results in Exhibit 9 reveal that the AP Calculus students performed relatively better in Calculus than in Geometry or Numbers and Equations. In the United States, compared to their overall average achievement, students performed better in Calculus and Numbers and Equations and worse in Geometry. Students in the Czech Republic performed better in Geometry than overall, and those in France had a relative strength in Calculus. Students in Germany did relatively better in Geometry and relatively worse in Calculus than they did overall. Whereas the Greek students had a relative weakness in Geometry, the Swiss students were particularly strong in that area. Students in both Lithuania and Sweden showed relative strength in Numbers and Equations, but had more difficulty in Calculus than they did overall. Achievement in both Austria and Denmark was relatively lower in Numbers and Equations, and relatively higher in Geometry. Students in Italy had relatively lower achievement in Numbers and Equations, and relatively higher achievement in Calculus.

For Australia, Canada, the Russian Federation, and Slovenia, performance in the individual content areas was not significantly different from their overall advanced mathematics scores.

Exhibit 9: Profiles of Performance in Mathematics Content Areas for Students Having Taken Advanced Mathematics – Final Year of Secondary School*



* See Mullis and others, 1998 Appendix A for characteristics of the students sampled.

† Met guidelines for sample participation rates only after replacement schools were included (see Mullis and others, 1998 Appendix B for details).

1 National Desired Population does not cover all of International Desired Population (see Mullis and others, 1998 Table B.4).

2 National Defined Population covers less than 90 percent of National Desired Population (see Mullis and others, 1998 Table B.4).

Exhibit 10: Achievement in Advanced Mathematics Content Areas by Gender for Students Having Taken Advanced Mathematics – Final Year of Secondary School*

Country	MTCI	Advanced Mathematics Content Areas Average Achievement Scale Scores					
		Numbers & Equations (17 items)		Calculus (15 items)		Geometry (23 items)	
		Females	Males	Females	Males	Females	Males
■ AP Calculus Students		549 (3.5)	560 (3.9)	601 (4.5)	▲ 618 (5.2)	523 (4.4)	▲ 541 (5.0)
Canada	16%	496 (4.5)	▲ 526 (5.6)	484 (4.9)	▲ 521 (5.5)	482 (4.6)	▲ 516 (5.3)
[2] Cyprus	9%	497 (7.0)	▲ 518 (6.5)	562 (8.0)	559 (5.0)	512 (8.5)	520 (5.2)
Czech Republic	11%	427 (10.5)	▲ 510 (11.3)	417 (8.3)	▲ 488 (11.0)	461 (7.2)	▲ 543 (12.1)
France	20%	544 (3.9)	551 (5.4)	544 (4.1)	▲ 569 (4.3)	529 (4.8)	▲ 555 (5.7)
† Germany	26%	446 (5.1)	▲ 475 (6.2)	442 (5.2)	▲ 471 (5.6)	480 (5.6)	▲ 498 (7.0)
† Greece	10%	537 (10.4)	540 (9.1)	536 (12.0)	540 (8.2)	485 (15.4)	505 (7.5)
[1]‡ Lithuania	3%	526 (5.4)	▲ 568 (3.0)	478 (4.8)	▲ 518 (4.3)	491 (5.8)	▲ 539 (3.6)
[2] Russian Federation	2%	533 (9.8)	▲ 576 (9.6)	512 (10.9)	▲ 560 (8.9)	525 (10.5)	▲ 570 (8.9)
Sweden	16%	511 (5.6)	529 (6.4)	472 (4.9)	484 (6.0)	476 (5.1)	▲ 500 (5.5)
Switzerland	14%	488 (5.7)	▲ 536 (5.7)	486 (6.2)	▲ 536 (6.8)	522 (5.9)	▲ 569 (3.8)
Countries Not Satisfying Guidelines for Sample Participation Rates							
Australia	16%	511 (11.2)	523 (9.9)	525 (12.2)	533 (13.6)	485 (13.8)	505 (14.1)
[2] Austria	33%	385 (9.3)	▲ 455 (6.2)	412 (7.3)	▲ 486 (6.9)	433 (9.6)	▲ 509 (7.7)
[1] Italy	14%	441 (14.1)	472 (10.6)	521 (13.5)	520 (11.4)	472 (14.5)	485 (10.4)
United States	14%	447 (6.9)	▲ 470 (6.1)	439 (6.1)	460 (5.3)	408 (7.0)	▲ 439 (5.8)
Countries With Unapproved Sampling Procedures and Low Participation Rates							
Denmark	21%	498 (3.5)	507 (3.6)	491 (5.4)	▲ 517 (4.3)	519 (4.0)	531 (4.2)
Slovenia	75%	480 (10.8)	503 (13.0)	463 (7.9)	479 (8.2)	469 (8.9)	482 (9.6)
International Avg.		485 (2.1)	▲ 516 (2.0)	487 (2.0)	▲ 515 (1.9)	484 (2.2)	▲ 517 (2.0)

▲ = Difference from other gender statistically significant at .05 level, adjusted for multiple comparisons

* See Mullis and others, 1998 Appendix A for characteristics of the students sampled.

† Met guidelines for sample participation rates only after replacement schools were included (see Mullis and others, 1998 Appendix B for details).

1 National Desired Population does not cover all of International Desired Population (see Mullis and others, 1998 Table B.4).

2 National Defined Population covers less than 90 percent of National Desired Population (see Mullis and others, 1998 Table B.4).

( ) Standard errors appear in parentheses. Because results are rounded to the nearest whole number, some totals may appear inconsistent.

Exhibit 10 shows a number of statistically significant gender differences in achievement by content areas, all favoring males rather than females. The international average for males was significantly higher than the average for females on each of the content area scales, with the greatest difference in Geometry (33 scale score points) and the least in Calculus (28 scale score points).

For the AP Calculus students, there were significant gender differences in Calculus and in Geometry. The largest gender gap (18 scale score points) was in Geometry, while the smallest gap (11 scale score points) was in Numbers and Equations. The United States had significant gender

Exhibit 11: Advanced Mathematics Students' Reports on the Frequency of Calculator Use During the TIMSS Advanced Mathematics Test – Final Year of Secondary School*

Country	Did Not Use a Calculator		Used a Calculator Very Little (<5 Questions)		Used a Calculator Somewhat (5-10 Questions)		Used a Calculator Quite a Lot (>10 Questions)	
	Percent of Students	Average Achievement	Percent of Students	Average Achievement	Percent of Students	Average Achievement	Percent of Students	Average Achievement
■ AP Calculus Students	7 (1.0)	542 (9.0)	47 (1.8)	579 (5.4)	36 (1.8)	573 (6.5)	9 (1.0)	569 (8.9)
Australia	10 (1.8)	488 (25.0)	55 (2.2)	533 (15.4)	28 (1.8)	526 (12.7)	6 (1.2)	527 (17.5)
Austria	20 (2.7)	391 (16.1)	47 (2.3)	447 (9.8)	29 (2.7)	451 (6.0)	4 (0.8)	426 (14.5)
Canada	7 (0.7)	478 (12.8)	59 (1.6)	515 (5.4)	29 (1.5)	505 (5.6)	5 (0.8)	520 (12.7)
Cyprus	30 (2.1)	504 (8.4)	58 (2.4)	525 (6.0)	10 (1.8)	512 (17.2)	1 (0.4)	~ ~
Czech Republic	13 (1.6)	452 (16.1)	64 (1.7)	473 (11.8)	21 (1.3)	472 (15.1)	1 (0.4)	~ ~
Denmark	7 (0.9)	475 (9.9)	55 (1.4)	529 (3.7)	33 (1.5)	525 (5.0)	6 (0.7)	519 (9.2)
France	13 (1.6)	547 (8.5)	56 (2.4)	561 (4.2)	25 (1.7)	557 (6.8)	5 (0.7)	571 (12.6)
Germany	15 (1.6)	414 (8.0)	58 (1.7)	479 (6.0)	23 (1.0)	478 (6.3)	4 (0.6)	457 (14.2)
Greece	86 (2.2)	509 (6.6)	13 (2.0)	539 (14.6)	1 (0.4)	~ ~	0 (0.0)	~ ~
Italy	38 (5.1)	468 (18.9)	47 (3.6)	485 (9.6)	13 (2.8)	466 (11.2)	2 (0.5)	~ ~
Lithuania	r 40 (1.7)	516 (4.5)	50 (2.1)	524 (7.1)	8 (1.3)	539 (24.2)	1 (0.5)	~ ~
Russian Federation	r 50 (2.4)	551 (12.2)	41 (2.0)	556 (9.3)	8 (1.0)	506 (9.9)	1 (0.3)	~ ~
Slovenia	26 (2.4)	435 (10.1)	64 (2.4)	492 (9.8)	10 (1.3)	479 (12.1)	1 (0.4)	~ ~
Sweden	3 (0.7)	474 (21.0)	39 (2.0)	509 (7.3)	46 (2.1)	515 (4.9)	11 (1.2)	526 (10.1)
Switzerland	7 (0.9)	484 (12.3)	57 (1.6)	546 (5.8)	32 (1.3)	524 (5.8)	4 (0.5)	532 (18.2)
United States	14 (1.6)	388 (10.6)	55 (2.0)	443 (6.1)	26 (1.8)	459 (9.8)	5 (0.8)	497 (18.0)
International Avg.	24 (0.5)	473 (3.5)	51 (0.5)	510 (2.2)	22 (0.4)	501 (3.7)	4 (0.2)	508 (8.2)

*See Mullis and others, 1998 Appendix A for characteristics of the students sampled.

( ) Standard errors appear in parentheses. Because results are rounded to the nearest whole number, some totals may appear inconsistent.

A tilde (~) indicates insufficient data to report achievement.

Countries shown in italics did not satisfy one or more guidelines for sample participation rates or student sampling (see Mullis and others, 1998 Figure B.6)

differences in only two content areas. The largest gender gap (31 scale score points) was in Geometry and the smallest gap (23 scale score points) was in Numbers and Equations.

Countries showing significant gender differences in all three content areas include Canada, the Czech Republic, Germany, Lithuania, the Russian Federation, Switzerland, and Austria. Countries showing significant gender differences in achievement in only one content area include Cyprus, Sweden, and Denmark. Four countries showed no significant gender differences –Greece, Australia, Italy, and Slovenia.

How Does Calculator Use Relate to Performance on the TIMSS Advanced Mathematics Test?

Since high school students use calculators as a matter of course in many countries, final-year students were given the option of using a calculator when taking the TIMSS tests. Exhibit 11 summarizes the students' reports on how frequently they used a calculator during the testing session. As presented in the exhibit, during the TIMSS

Advanced Mathematics testing session, 24% of students reported they “Did Not Use a Calculator,” 51% reported using a calculator “Very Little” (less than five questions), 22% reported using a calculator “Somewhat” (five to ten questions), and only 4% reported using a calculator “Quite a Lot” (more than ten questions).

Advanced mathematics students in most countries reported using a calculator at least “Somewhat” on the TIMSS Advanced Mathematics test. The exceptions to this were Greece, Italy, Lithuania, and the Russian Federation where more than one-third of the students reported not using a calculator at all. This lack of calculator usage is sharply contrasted by the AP Calculus students where very few students reported not using a calculator at all (7%). In only three countries (France, Sweden, and the United States) did there appear to be a consistent relationship between mathematics achievement and calculator use, with achievement increasing as calculator use increased. For all other countries, there was not a clear relationship, however, it is noted that in all countries those students reporting not using a calculator on the TIMSS test performed worse than those students reporting use at any level.

Student Achievement in Physics

How Does Physics Performance of Students in Advanced Placement Physics Programs Compare with Students Internationally?

Exhibit 12 presents the average achievement in physics for 16 countries, including the United States and the AP Physics students. Countries[1] with triangles pointing up next to their average achievement performed significantly above the international average scale score of 501. The AP Physics students, with a scale score average of 529, scored significantly above the international average. Other countries scoring above the international average include Norway, Sweden, the Russian Federation, and Denmark. Countries with triangles pointing down had average achievement significantly below the international average. The United States, with a scale score average of 423, scored significantly below the international average. Other countries scoring below the international average include Switzerland, Canada, France, the Czech Republic, and Austria.

In contrast to these results, the 1998 NCES report, *Pursuing Excellence*, indicates that the performance of United States twelfth graders with Advanced Placement Physics instruction were ranked 13th out of 16 countries.[2] This report showed the AP Physics students with an average achievement of 474 on the TIMSS Physics test.

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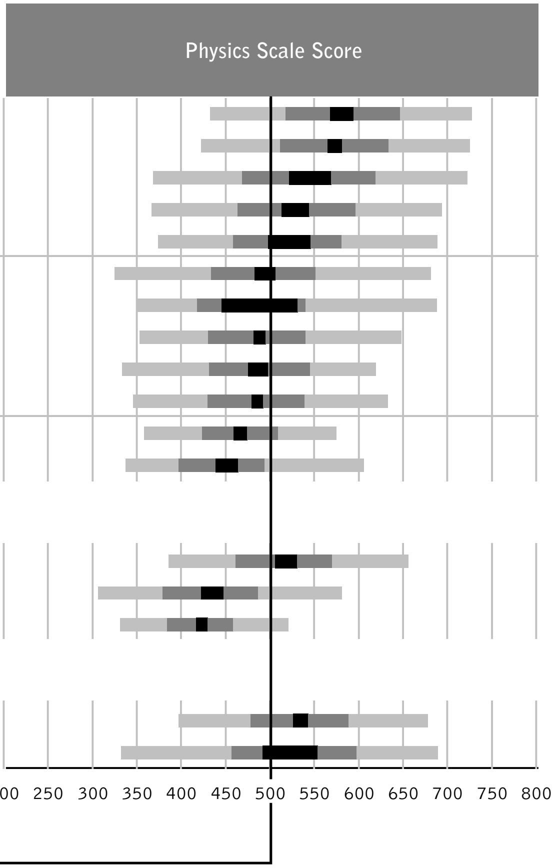
[1] AP students will be referred to as a 'country' for ease of discussion

[2] U.S. Department of Education. National Center for Education Statistics, *Pursuing Excellence: A Study of U.S. Twelfth-Grade Mathematics and Science Achievement in International Context,* NCES98-049. Washington, DC: U.S. Government Printing Office, 1998.

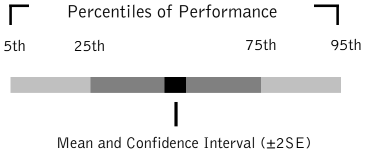
Exhibit 12: Distributions of Physics Achievement for Students Having Taken Physics – Final Year of Secondary School*

Country		Average Achievement	PTCI[‡]	Average Age
[†] Norway	▲	581 (6.5)	8%	19.0
Sweden	▲	573 (3.9)	16%	18.9
[2] Russian Federation	▲	545 (11.6)	2%	16.9
■ AP Physics Students	▲	529 (7.7)		17.9
[†] Germany	●	522 (11.9)	8%	19.1
[2] Cyprus	●	494 (5.8)	9%	17.7
[1] Latvia (LSS)	●	488 (21.5)	3%	18.0
Switzerland	▼	488 (3.5)	14%	19.5
[†] Greece	●	486 (5.6)	10%	17.7
Canada	▼	485 (3.3)	14%	18.6
France	▼	466 (3.8)	20%	18.2
Czech Republic	▼	451 (6.2)	11%	18.1
Countries Not Satisfying Guidelines for Sample Participation Rates				
Australia	●	518 (6.2)	13%	17.7
[2] Austria	▼	435 (6.4)	33%	19.1
United States	▼	423 (3.3)	14%	18.0
Countries With Unapproved Sampling Procedures and Low Participation Rates				
Denmark	▲	534 (4.2)	3%	19.1
Slovenia	●	523 (15.5)	39%	18.8



International Average = 501 (2.2)
Average of all country means

- ▲ Country mean significantly higher than international mean
- ▼ Country mean significantly lower than international mean
- ● No statistically significant difference between country mean and international mean



* See Mullis and others, 1998 Appendix A for characteristics of the students sampled.

‡ The Physics Test Coverage Index (PTCI) is an estimate of the percentage of the school-leaving age cohort covered by the TIMSS final-year physics student sample (see Mullis and others, 1998 Appendix B for more information).

Because population coverage falls below 65%, Latvia is annotated LSS for Latvian Speaking Schools only.

† Met guidelines for sample participation rates only after replacement schools were included (see Mullis and others, 1998 Appendix B for details).

1 National Desired Population does not cover all of International Desired Population (see Mullis and others, 1998 Table B.4).

2 National Defined Population covers less than 90 percent of National Desired Population (see Mullis and others, 1998 Table B.4).

( ) Standard errors appear in parentheses. Because results are rounded to the nearest whole number, some totals may appear inconsistent.

The upper part of the exhibit shows, in decreasing order of average achievement, the 11 countries that were judged to have met the TIMSS requirements for testing a representative sample of the students having taken physics in accordance with their national definition. While some countries had more success in locating these physics students and encouraging them to participate in the testing, others encountered resistance from schools and students and failed to reach the overall participation rate of 75% or higher (for schools and students combined) specified by the TIMSS guidelines (i.e., Australia, Austria, and the United States). Denmark and Slovenia also had difficulties in prescribed sampling methods and as a consequence are reported in separate panels. Because the AP Physics students represent the group of interest for this report, their results are presented in the top panel of the exhibits together with countries that met the overall participation rates.

The average age of students gives some idea of the years of formal schooling in the participating countries. Because of different policies regarding the age for starting school and for retention it is important to note that students of similar age have not necessarily had the same number of years of formal schooling. Furthermore, the students in the TIMSS countries have not studied the same curriculum throughout their schooling.

The results in Exhibit 12, especially the visual representations of the performance distributions within each country, suggest some similarity in average performance among many of the countries, although there is variation from the top- to the bottom-performing ones. For instance, the AP Physics students performed very similar to students in Germany, while varying considerably from students in the United States. In contrast to the overlapping performance across a number of the countries in their average achievement (shown by the dark boxes at the distribution midpoints representing the 95% confidence intervals around the means), the range in within-country performance usually was substantial (shown by the 5th and 95th percentiles, representing the extremes of lower and higher achievement). When comparing the performance of the United States students to the AP Physics students, the United States students scoring at the highest level of achievement are performing at the mean of the AP Physics students. Complementing this information, percentiles and standard deviations of achievement at the 5th, 25th, 50th, 75th, and 95th percentiles for each country and the AP Physics students are presented in Exhibit B.3 in Appendix B.

Exhibit 13 allows comparison of overall average achievement between countries. It shows whether or not the differences in average achievement between pairs of countries are statistically significant.[3] Selecting a country of interest and reading across the table, a triangle pointing up indicates significantly higher performance than the country listed across the top, a dot indicates no significant difference, and a triangle pointing down indicates significantly lower performance.

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[3] The significance tests in Exhibit 12 are based on a Bonferroni procedure for multiple comparisons that holds to 5% the probability of erroneously declaring the mean of one country to be different from that of another.

Exhibit 13: Multiple Comparisons of Physics Achievement for Students Having Taken Physics – Final Year of Secondary School*

Instructions: Read ***across*** the row for a country to compare performance with the countries listed in the heading of the chart. The symbols indicate whether the mean achievement of the country in the row is significantly lower than that of the comparison country, significantly higher than that of the comparison country, or if there is no statistically significant difference between the two countries.‡

	Norway	Sweden	Russian Federation	*Denmark*	AP Physics Students	*Slovenia*	Germany	*Australia*	Cyprus	Switzerland	Latvia (LSS)	Greece	Canada	France	Czech Republic	*Austria*	*United States*
Norway		●	●	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
Sweden	●		●	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
Russian Federation	●	●		●	●	●	●	●	▲	▲	●	▲	▲	▲	▲	▲	▲
Denmark	▼	▼	●		●	●	●	●	▲	▲	●	▲	▲	▲	▲	▲	▲
AP Physics Students	▼	▼	●	●		●	●	●	▲	▲	●	▲	▲	▲	▲	▲	▲
Slovenia	▼	▼	●	●	●		●	●	●	●	●	●	●	▲	▲	▲	▲
Germany	▼	▼	●	●	●	●		●	●	●	●	●	▲	▲	▲	▲	▲
Australia	▼	▼	●	●	●	●	●		●	▲	●	▲	▲	▲	▲	▲	▲
Cyprus	▼	▼	▼	▼	▼	●	●	●		●	●	●	●	▲	▲	▲	▲
Switzerland	▼	▼	▼	▼	▼	●	●	▼	●		●	●	●	▲	▲	▲	▲
Latvia (LSS)	▼	▼	●	●	●	●	●	●	●	●		●	●	●	●	●	▲
Greece	▼	▼	▼	▼	▼	●	●	▼	●	●	●		●	▲	▲	▲	▲
Canada	▼	▼	▼	▼	▼	●	▼	▼	●	●	●	●		▲	▲	▲	▲
France	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	●	▼	▼		●	▲	▲
Czech Republic	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	●	▼	▼	●		●	▲
Austria	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	●	▼	▼	▼	●		●
United States	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	●	

Countries are ordered by average achievement across the heading and down the rows.

- ▲ Mean achievement significantly higher than comparison country
- ● No statistically significant difference from comparison country
- ▼ Mean achievement significantly lower than comparison country

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* See Mullis and others, 1998 Appendix A for characteristics of the students sampled.

‡ Statistically significant at .05 level, adjusted for multiple comparisons.

Countries shown in italics did not satisfy one or more guidelines for sample participation rates or student sampling (see Mullis and others, 1998 Figure B.6).

Because population coverage falls below 65%, Latvia is annotated LSS for Latvia Speaking School only.

In terms of average physics achievement, the AP Physics students were significantly outperformed by only two countries: Norway and Sweden. The AP Physics students performed about the same as students in the Russian Federation, Denmark, Slovenia, Germany, Australia, and Latvia. Among these countries, the Russian Federation (2%) and Latvia (3%) tested a rather small percentage of their school-leaving cohort in physics, and Denmark and Slovenia did not meet the TIMSS sampling guidelines. The AP Physics students performed better than students in Cyprus, Switzerland, Greece, Canada, France, Czech Republic, Austria and the United States. The United States was outperformed by all other participating countries. It should be noted that Austria (33%) had a comparatively higher PTCI than the most other participants, as did France (20%) implying that relatively large numbers of students in these countries had studied secondary school physics.

How Do Students Who Pass the AP Physics Exam Perform on the TIMSS Physics Test?

A student is considered to have passed the AP Physics Exam if she or he obtains an AP Exam grade of 3 or above. Exhibit 14 shows the average achievement of AP Physics students receiving this passing grade compared with those AP Physics students scoring below 3. Students could choose to take the AP Physics B or one or both of the AP Physics C Exams. The Physics B Exam is reported as a single grade, while the Physics C Exam is reported as two separate grades – Mechanics (M) and Electricity and Magnetism (E & M).

For all the AP Physics Examinations, students receiving a grade of 3 or above performed better on the TIMSS Physics test than those who did not. For the Physics B Exam, students receiving a grade of 3 or above had a scale score average of 586, while those receiving a grade of less than 3 had a scale score average of 511, for a difference of 75 scale score points. A similar difference of 77 scale score points is seen in the students who took the Physics C (E & M) Exam. AP Physics students receiving a grade of 3 or above on this exam scored an average of 600, while those receiving a grade of less than 3 had an average of 523. The smallest difference, 50 scale score points, was seen in students who took the Physics C (M) exam. AP Physics students with a grade of 3 or above on this exam had average achievement of 572 while those receiving a grade of less than 3 had an average achievement of 522. Furthermore, students who obtained a grade of 3 or above on any of the AP Physics Exams obtained an average score of 577 (7.2) on the TIMSS Physics test, performing at the same level as Norway, Sweden and the Russian Federation and outperforming all other countries.

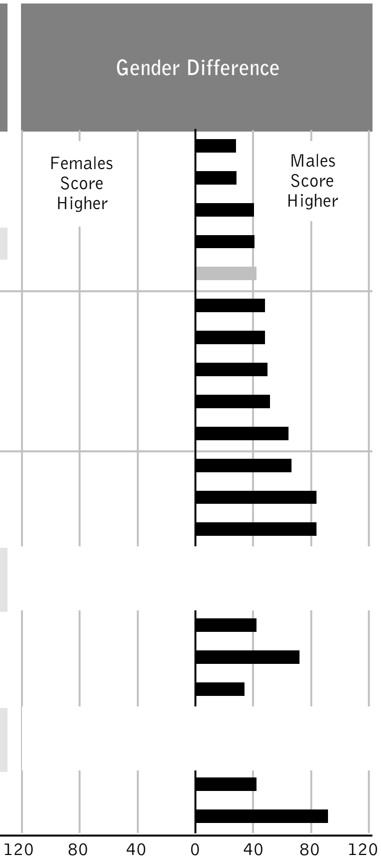
Exhibit 14: Average Achievement of AP Physics Students in Physics by Results in AP Physics Exam

Score on AP Physics Exam	Average Achievement
Less than 3 on AP Physics B	511 (8.5)
3 or better on AP Physics B	586 (9.8)
Less than 3 on AP Physics C (Electricity and Magnetism)	523 (8.0)
3 or better on AP Physics C (Electricity and Magnetism)	600 (7.6)
Less than 3 on AP Physics C (Mechanics)	522 (8.6)
3 or better on AP Physics C (Mechanics)	572 (9.2)

( ) Standard errors appear in parentheses.

Exhibit 15: Gender Differences in Physics Achievement for Students Having Taken Physics – Final Year of Secondary School*

Country	Males		Females		Difference	PTCI
	Percent of Students	Average Achievement	Percent of Students	Average Achievement		
† Greece	68 (2.1)	495 (6.1)	32 (2.1)	468 (8.1)	28 (10.1)	10%
France	61 (2.0)	478 (4.2)	39 (2.0)	450 (5.6)	28 (7.0)	20%
2 Cyprus	63 (2.5)	509 (8.9)	37 (2.5)	470 (7.1)	40 (11.4)	9%
■ AP Physics Students	68 (2.2)	543 (8.5)	32 (2.2)	503 (8.8)	40 (12.3)	
1 Latvia (LSS)	51 (3.7)	509 (19.0)	49 (3.7)	467 (22.6)	42 (29.5)	3%
Canada	57 (3.2)	506 (6.0)	43 (3.2)	459 (6.3)	47 (8.7)	14%
Canada	57 (3.2)	506 (6.0)	43 (3.2)	459 (6.3)	47 (8.7)	14%
Sweden	67 (3.4)	589 (5.1)	33 (3.4)	540 (5.3)	49 (7.4)	16%
† Norway	74 (1.8)	594 (6.3)	26 (1.8)	544 (9.3)	51 (11.2)	8%
† Germany	69 (3.0)	542 (14.3)	31 (3.0)	479 (9.1)	64 (17.0)	8%
2 Russian Federation	54 (2.0)	575 (9.9)	46 (2.0)	509 (15.3)	66 (18.2)	2%
Czech Republic	38 (2.4)	503 (8.8)	62 (2.4)	419 (3.9)	83 (9.7)	11%
Switzerland	51 (1.8)	529 (5.2)	49 (1.8)	446 (3.6)	83 (6.3)	14%
Countries Not Satisfying Guidelines for Sample Participation Rates						
Australia	66 (3.8)	532 (6.7)	34 (3.8)	490 (8.4)	42 (10.8)	13%
2 Austria	38 (3.5)	479 (8.1)	62 (3.5)	408 (7.4)	71 (11.0)	33%
United States	52 (2.4)	439 (4.3)	48 (2.4)	405 (3.1)	33 (5.3)	14%
Countries With Unapproved Sampling Procedures and Low Participation Rates						
Denmark	80 (2.3)	542 (5.2)	20 (2.3)	500 (8.1)	42 (9.6)	3%
Slovenia	72 (3.7)	546 (16.3)	28 (3.7)	455 (18.7)	91 (24.8)	39%



International Averages		
Males	Females	Difference
523	469	54

(Average of all country means)

■ Gender difference statistically significant at .05 level.

▨ Gender difference not statistically significant.

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* See Mullis and others, 1998 Appendix A for characteristics of the students sampled.

† Met guidelines for sample participation rates only after replacement schools were included (see Mullis and others, 1998 Appendix B for details).

1 National Desired Population does not cover all of International Desired Population (see Mullis and others, 1998 Table B.4).

2 National Defined Population covers less than 90 percent of National Desired Population (see Mullis and others, 1998 Table B.4).

( ) Standard errors appear in parentheses. Because results are rounded to the nearest whole number, some differences may appear inconsistent.

Because population coverage falls below 65%, Latvia is annotated LSS for Latvian Speaking Schools only.

How Does Performance in Physics Compare by Gender and Race/Ethnicity?

Exhibit 15 shows average achievement in physics separately for males and females for each country, as well as the difference between the averages. The graphic representation of the gender difference, shown by the bar for each country, shows that the direction of the difference favored males in every country, and that the difference was statistically significant, as indicated by a darkened bar, in all but one of the participating countries. The AP Physics students showed a statistically significant gender difference of 40 scale score points, favoring males. This difference was more than the United States gender difference of 33 scale score points which also favored males. Generally, there was a larger gender difference internationally (international average difference of 54 scale-score points), and especially large gender differences (greater than 80 scale score points) were found in the Czech Republic, Switzerland and Slovenia. Only in Latvia (LSS) was the average physics score for males not significantly greater than that for females, although this may have been partly the result of a larger than usual sampling variance.

Exhibit 15 also shows the percentage of upper secondary school students who have taken physics courses by gender. The results reveal that many more (at least 20%) males than females have taken physics in Greece, France, Cyprus, AP Physics students, Sweden, Norway, Germany, Australia, Denmark, and Slovenia. More males than females have also taken physics in several other countries, although the differences are not as large (Canada 14% and the Russian Federation 8%). The percentages of males and females taking physics courses are nearly identical in Latvia (LSS), Switzerland, and the United States. In contrast, more females than males have taken physics courses in only two of the participating countries – the Czech Republic (24%) and Austria (24%). Standard deviations of achievement in physics by gender are presented in Exhibit B.4 in Appendix B.

Exhibit 16 shows the TIMSS physics results for the AP Physics students by race/ethnicity. The sample selected was predominantly White (Not Hispanic) with 66% of students identifying themselves with this group. The average scale score for White (Not Hispanic) students was 543. The next largest group was Asian or Pacific Islander with 26% of the sampled students. The average scale

Exhibit 16: Average Achievement of AP Physics Students by Students' Race/Ethnicity

Race/Ethnicity	Percent of Students	Average Achievement
White (Not Hispanic)	66 (3.7)	543 (7.1)
Black (Not Hispanic)	1 (0.2)	~ ~
[1] Hispanic	4 (0.9)	481 (29.4)
[2] Asian or Pacific Islander	26 (3.7)	518 (13.4)
[3] American Indian or Alaskan Native	0 (0.1)	~ ~
Other	4 (0.7)	475 (46.4)

1 "Hispanic" means someone who is Mexican, Mexican American, Chicano, Puerto Rican, Cuban, or from some other Spanish or Hispanic background.

2 "Asian or Pacific Islander" means someone who is Chinese, Japanese, Korean, Filipino, Vietnamese, Asian American, or from some other Asian or Pacific Island background.

3 "American Indian or Alaskan Native" means someone who is from one of the American Indian tribes, or from one of the original people of Alaska.

( ) Standard errors appear in parentheses.

score for Asian or Pacific Islander was 518. Hispanic and Other students each made up approximately 4% of the sample. The average scale score for Hispanic students was 481, while Other students scored 475. Due to the low percentage of Black (Not Hispanic) students and American Indian or Alaskan Native students in the sample, their achievement data is not presented.

How Does Performance Compare Across Content Areas?

TIMSS measured achievement in different content areas of physics in order to gather more information about what each country's population of physics students know and can do. The physics test for final year students was designed to enable reporting by five content areas.[4] These content areas are:

- Mechanics
- Electricity and Magnetism
- Heat
- Wave Phenomena
- Modern Physics

As well as scaling the complete physics item pool to obtain an overall physics scale score, TIMSS scaled each of the five physics content areas separately to facilitate analyses at the content level. Given that the test was designed to include items from different curricular areas, it is important to examine whether participating countries have particular strengths and weaknesses in their achievement.

Exhibit 17 summarizes the country averages and standard errors on each content scale for each country. As indicated earlier the international average for each of the content scales was arbitrarily set to be 500 with a standard deviation of 100.[5] The countries that performed best on the overall physics test sometimes did well in the five content areas for which there were separate results, and those that did poorly overall tended to do so in each of the content areas.

The AP Physics students, who performed above the international average in physics overall, also performed above the international average in two of the five content areas: Mechanics and Modern Physics. The AP Physics students' highest rank (4th) was in Electricity and Magnetism, and their lowest rank (11th) was in Heat. The United States students, who performed below the international average in physics overall, also performed below the international average in all of the content areas. The United States highest rank (15th) was in Modern Physics, and their lowest rank (17th, last) was in Electricity and Magnetism. Most countries, however, showed particular strengths or weaknesses. Canada, for instance, scored at the international average in Heat and Modern Physics, while scoring significantly below the international average in the remaining content areas.

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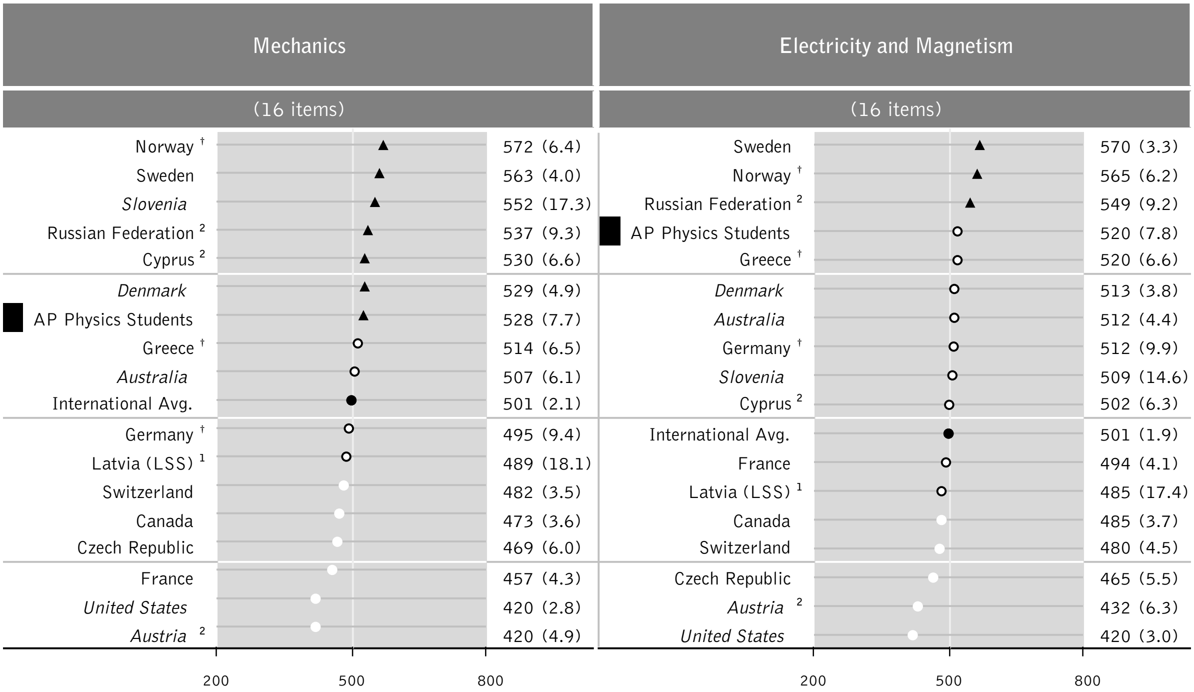
[4] See the "Test Development" section of Appendix B in Mullis, I.V.S., Martin, M.O., Beaton, A.E., Gonzalez, E.J., Kelly, D.L., and Smith, T.A. (1998), *Mathematics and Science Achievement in the Final Year of Secondary School: IEA's Third International Mathematics and Science Study*, Chestnut Hill, MA: Boston College.

[5] Final revisions of the data resulted in international averages of 501 for some of the physics content scales.

Exhibit 17: Average Achievement in Physics Content Areas for Students Having Taken Physics – Final Year of Secondary School*



Mechanics (16 items)			Electricity and Magnetism (16 items)		
Norway[†]	▲	572 (6.4)	Sweden	▲	570 (3.3)
Sweden	▲	563 (4.0)	Norway[†]	▲	565 (6.2)
Slovenia	▲	552 (17.3)	Russian Federation[2]	▲	549 (9.2)
Russian Federation[2]	▲	537 (9.3)	■ AP Physics Students	○	520 (7.8)
Cyprus[2]	▲	530 (6.6)	Greece[†]	○	520 (6.6)
Denmark	▲	529 (4.9)	*Denmark*	○	513 (3.8)
■ AP Physics Students	▲	528 (7.7)	*Australia*	○	512 (4.4)
Greece[†]	○	514 (6.5)	Germany[†]	○	512 (9.9)
Australia	○	507 (6.1)	*Slovenia*	○	509 (14.6)
International Avg.	●	501 (2.1)	Cyprus[2]	○	502 (6.3)
Germany[†]	○	495 (9.4)	International Avg.	●	501 (1.9)
Latvia (LSS)[1]	○	489 (18.1)	France	○	494 (4.1)
Switzerland	⚪	482 (3.5)	Latvia (LSS)[1]	○	485 (17.4)
Canada	⚪	473 (3.6)	Canada	⚪	485 (3.7)
Czech Republic	⚪	469 (6.0)	Switzerland	⚪	480 (4.5)
France	⚪	457 (4.3)	Czech Republic	⚪	465 (5.5)
United States	⚪	420 (2.8)	*Austria*[2]	⚪	432 (6.3)
Austria[2]	⚪	420 (4.9)	*United States*	⚪	420 (3.0)

▲ Country average significantly higher than international average

○ Country average not significantly different from international average

⚪ Country average significantly lower than international average

Significance tests adjusted for multiple comparisons

* See Mullis and others, 1998 Appendix A for characteristics of the students sampled.

† Met guidelines for sample participation rates only after replacement schools were included (see Mullis and others, 1998 Appendix B for details).

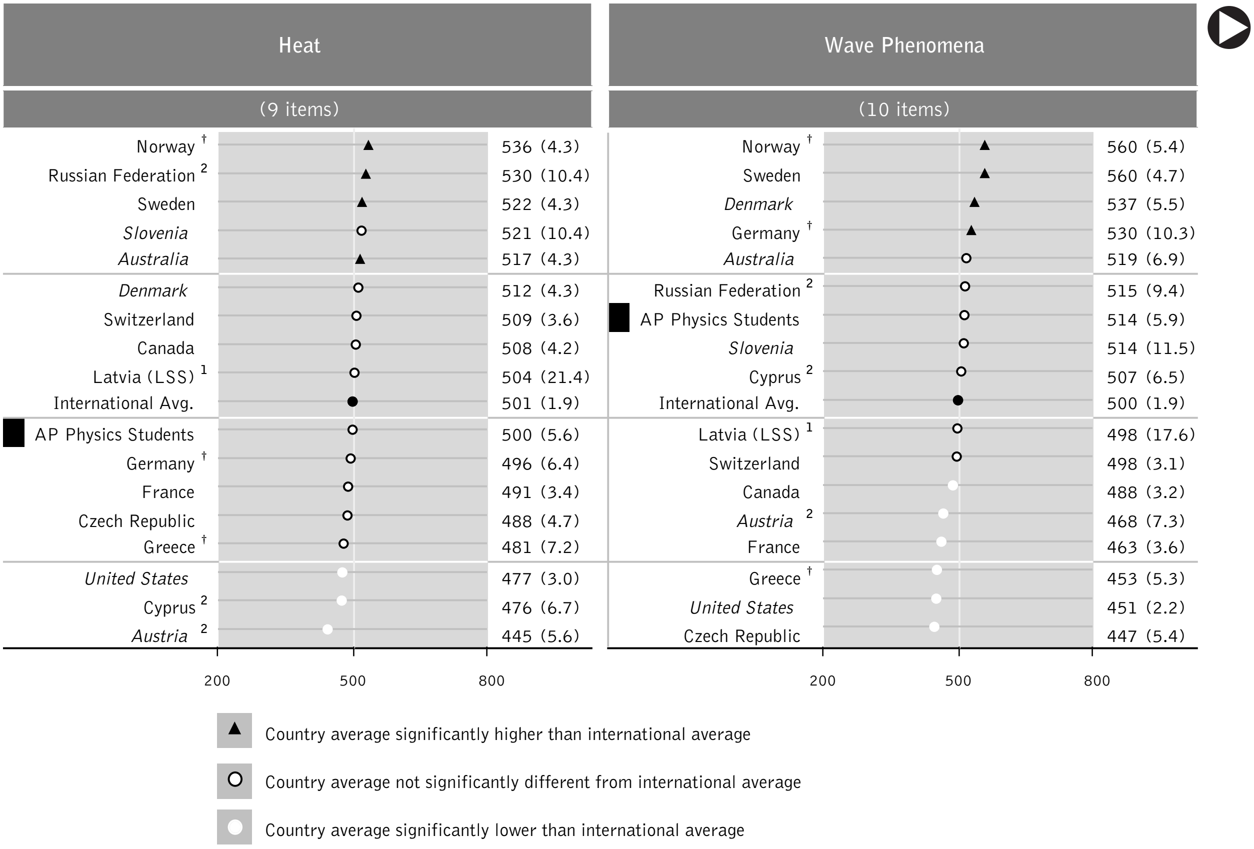
1 National Desired Population does not cover all of International Desired Population (see Mullis and others, 1998 Table B.4).

2 National Defined Population covers less than 90 percent of National Desired Population (see Mullis and others, 1998 Table B.4).

( ) Standard errors appear in parentheses. Because results are rounded to the nearest whole number, some differences may appear inconsistent.

Countries shown in *italics* did not satisfy one or more guidelines for sample participation rates or student sampling (see Mullis and others, 1998 Figure B.6)

Exhibit 17 (Continued): Average Achievement in Physics Content Areas for Students Having Taken Physics – Final Year of Secondary School*



Heat (9 items)		
Norway[†]	▲	536 (4.3)
Russian Federation[2]	▲	530 (10.4)
Sweden	▲	522 (4.3)
Slovenia	○	521 (10.4)
Australia	▲	517 (4.3)
Denmark	○	512 (4.3)
Switzerland	○	509 (3.6)
Canada	○	508 (4.2)
Latvia (LSS)[1]	○	504 (21.4)
International Avg.	●	501 (1.9)
■ AP Physics Students	○	500 (5.6)
Germany[†]	○	496 (6.4)
France	○	491 (3.4)
Czech Republic	○	488 (4.7)
Greece[†]	○	481 (7.2)
United States	⚪	477 (3.0)
Cyprus[2]	⚪	476 (6.7)
Austria[2]	⚪	445 (5.6)

Wave Phenomena (10 items)		
Norway[†]	▲	560 (5.4)
Sweden	▲	560 (4.7)
Denmark	▲	537 (5.5)
Germany[†]	▲	530 (10.3)
Australia	○	519 (6.9)
Russian Federation[2]	○	515 (9.4)
■ AP Physics Students	○	514 (5.9)
Slovenia	○	514 (11.5)
Cyprus[2]	○	507 (6.5)
International Avg.	●	500 (1.9)
Latvia (LSS)[1]	○	498 (17.6)
Switzerland	○	498 (3.1)
Canada	⚪	488 (3.2)
Austria[2]	⚪	468 (7.3)
France	⚪	463 (3.6)
Greece[†]	⚪	453 (5.3)
United States	⚪	451 (2.2)
Czech Republic	⚪	447 (5.4)

▲ Country average significantly higher than international average

○ Country average not significantly different from international average

⚪ Country average significantly lower than international average

Significance tests adjusted for multiple comparisons

* See Mullis and others, 1998 Appendix A for characteristics of the students sampled.

† Met guidelines for sample participation rates only after replacement schools were included (see Mullis and others, 1998 Appendix B for details).

1 National Desired Population does not cover all of International Desired Population (see Mullis and others, 1998 Table B.4).

2 National Defined Population covers less than 90 percent of National Desired Population (see Mullis and others, 1998 Table B.4).

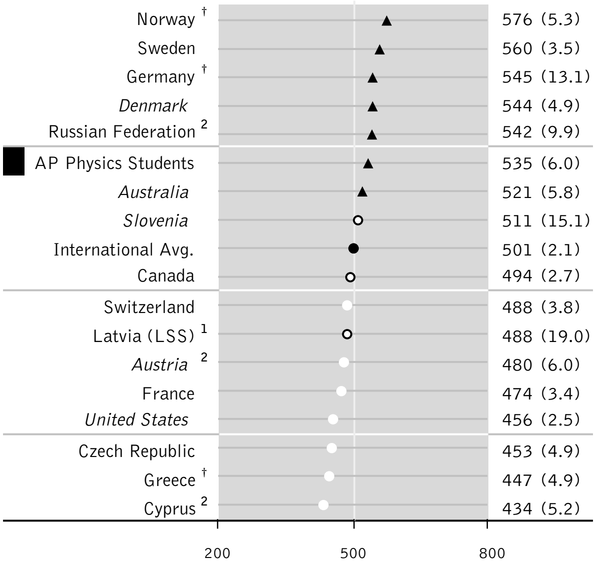
( ) Standard errors appear in parentheses. Because results are rounded to the nearest whole number, some differences may appear inconsistent.

Countries shown in *italics* did not satisfy one or more guidelines for sample participation rates or student sampling (see Mullis and others, 1998 Figure B.6)

Exhibit 17
(Continued)

Modern Physics: Particle, Quantum and Astrophysics, and Relativity

(14 items)



Norway [†]	576 (5.3)
Sweden	560 (3.5)
Germany [†]	545 (13.1)
Denmark	544 (4.9)
Russian Federation [2]	542 (9.9)
■ AP Physics Students	535 (6.0)
Australia	521 (5.8)
Slovenia	511 (15.1)
International Avg.	501 (2.1)
Canada	494 (2.7)
Switzerland	488 (3.8)
Latvia (LSS) [1]	488 (19.0)
Austria [2]	480 (6.0)
France	474 (3.4)
United States	456 (2.5)
Czech Republic	453 (4.9)
Greece [†]	447 (4.9)
Cyprus [2]	434 (5.2)

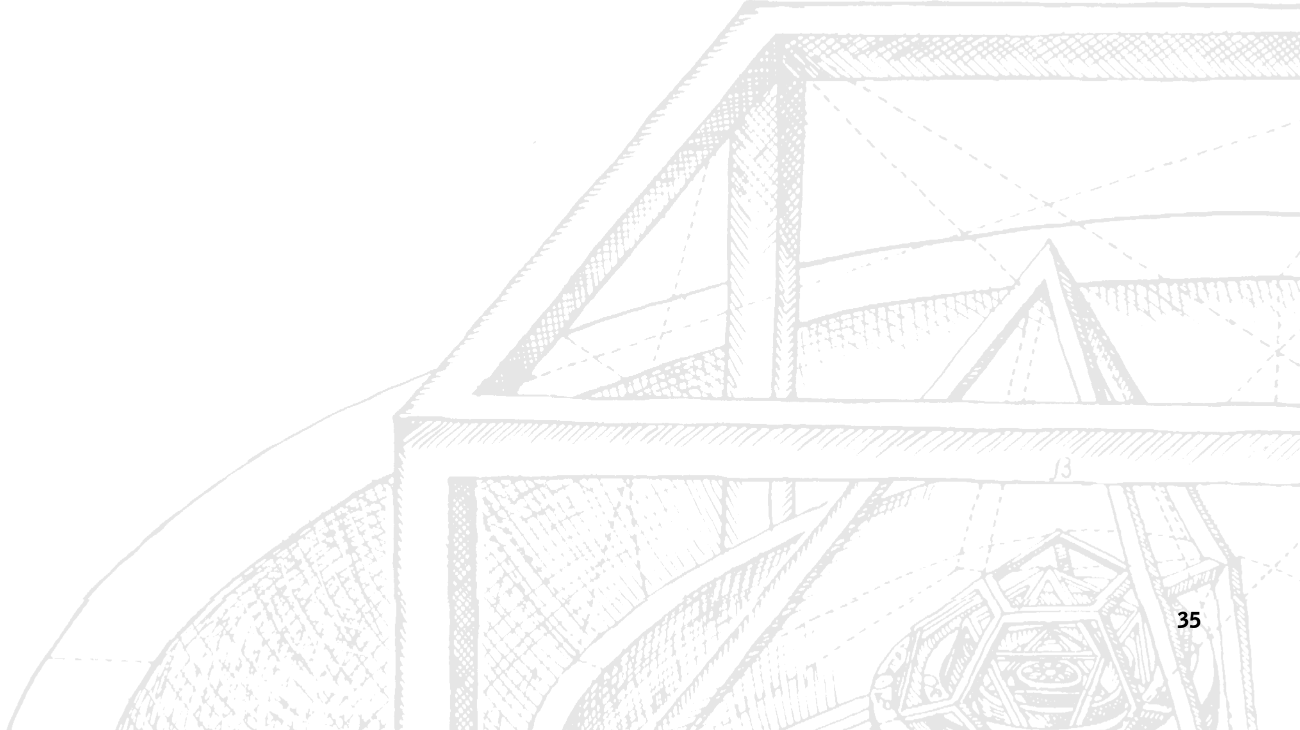
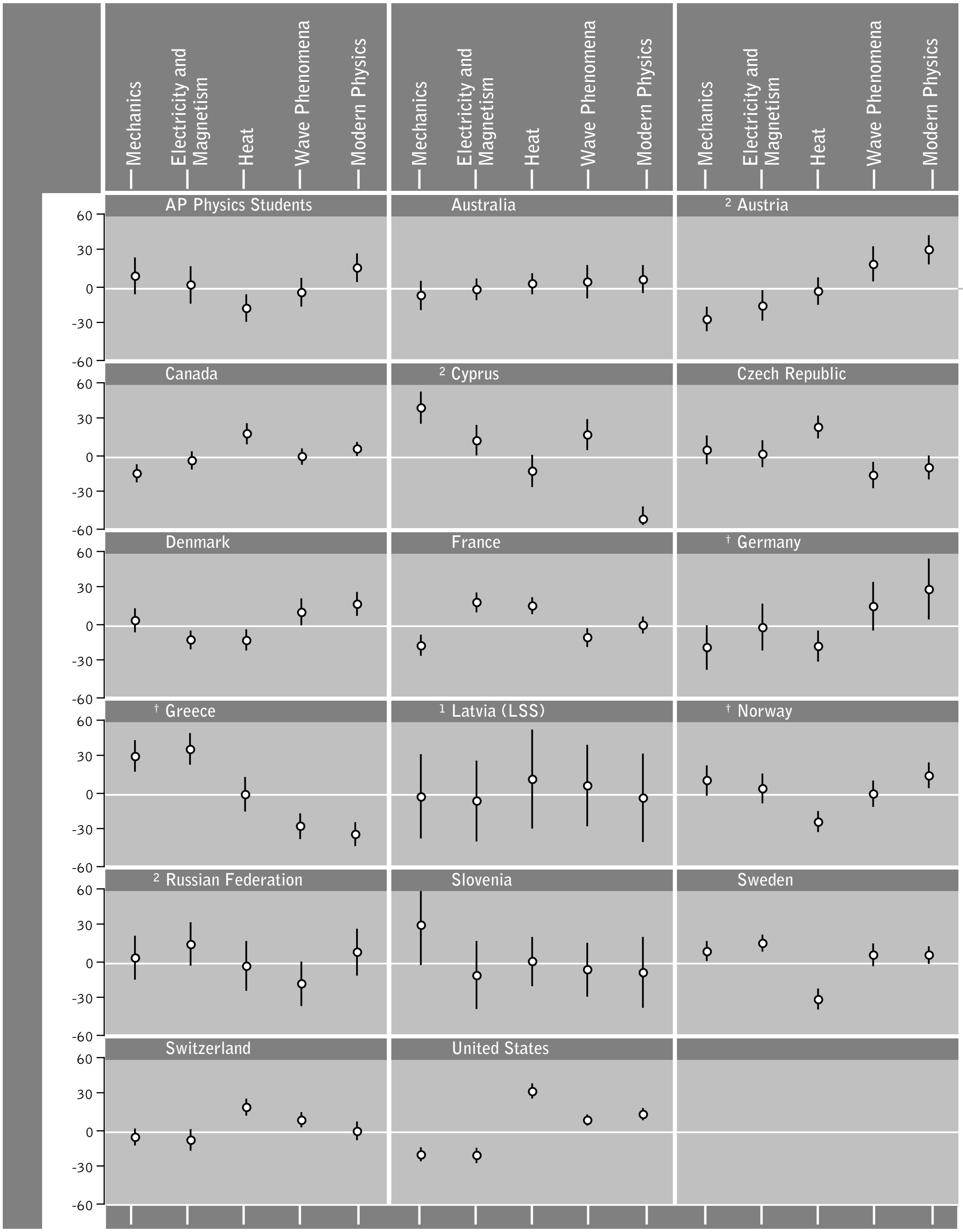


Exhibit 18: Profiles of Performance in Physics Content Areas for Students Having Taken Physics – Final Year of Secondary School*



* See Mullis and others, 1998 Appendix A for characteristics of the students sampled.

† Met guidelines for sample participation rates only after replacement schools were included (see Mullis and others, 1998 Appendix B for details).

1 National Desired Population does not cover all of International Desired Population (see Mullis and others, 1998 Table B.4).

2 National Defined Population covers less than 90 percent of National Desired Population (see Mullis and others, 1998 Table B.4).

Because population coverage falls below 65%, Latvia is annotated LSS for Latvian Speaking Schools only.

Exhibit 18 presents a visual profile of performance in the physics content areas in each country. In this profile, the comparison is with the country's overall average achievement, so that regardless of the performance of the country relative to that of other participants, particular strengths and weaknesses within the country can be identified. The horizontal line represents each country's overall average achievement in the five physics content areas, and the vertical lines indicate the 95% confidence intervals around the average achievement (hollow circle) in each of the five major content areas. If the hollow circle and corresponding 95% confidence interval is below the line, then the country performed significantly lower in that content area than it did overall. Similarly, if the hollow circle and corresponding 95% confidence interval is above the line, then the country performed significantly better in that content area than it did overall.

The results in Exhibit 18 indicate that the AP Physics students performed better in Modern Physics than on the test as a whole, around the same on Mechanics, Electricity and Magnetism and Wave Phenomena, and less well on Heat. The United States students performed better in Heat, Wave Phenomena, and Modern Physics than on the test as a whole and less well on Mechanics and Electricity and Magnetism. Students in the Czech Republic performed better in Heat than overall, and those in France had a relative strength in Heat and Electricity and Magnetism. Students in Germany did relatively better in Modern Physics and relatively worse in Heat than they did overall. Whereas the Greek students had a relative weakness in Wave Phenomena and Modern Physics, the Austrian students were particularly strong in these areas. Students in Cyprus showed relative strength in Mechanics, but had more difficulty in Modern Physics than they did overall. Achievement in both Norway and Sweden was relatively lower in Heat, but around the same in all other content areas as on the test as a whole.

For Australia, Latvia, the Russian Federation, and Slovenia, performance in the individual content areas was not significantly different from their overall advanced mathematics scores.

Exhibit 19: Achievement in Physics Content Areas by Gender for Students Having Taken Physics – Final Year of Secondary School*

Country	PTCI	Physics Content Areas Average Achievement Scale Scores					
		Mechanics (16 items)		Electricity and Magnetism (16 items)		Heat (9 items)	
		Females	Males	Females	Males	Females	Males
■ AP Physics Students		499 (7.7)	▲ 543 (8.2)	492 (8.9)	▲ 535 (8.5)	490 (7.1)	506 (6.5)
Canada	14%	440 (5.7)	▲ 499 (6.6)	468 (6.5)	497 (6.2)	492 (8.1)	520 (5.2)
[2] Cyprus	9%	496 (10.3)	▲ 551 (9.6)	494 (7.4)	507 (8.5)	461 (11.2)	484 (9.8)
Czech Republic	11%	440 (4.8)	▲ 514 (8.4)	443 (3.3)	▲ 501 (8.7)	472 (4.5)	▲ 513 (6.6)
France	20%	437 (5.5)	▲ 470 (5.6)	491 (5.2)	495 (4.2)	487 (5.7)	496 (4.0)
† Germany	8%	453 (10.6)	▲ 515 (9.6)	491 (7.7)	522 (12.1)	461 (10.6)	▲ 513 (6.3)
† Greece	10%	489 (7.2)	▲ 525 (7.0)	515 (11.0)	522 (6.5)	460 (10.5)	490 (8.1)
[1] Latvia (LSS)	3%	468 (19.8)	▲ 509 (15.2)	474 (18.4)	496 (16.8)	484 (23.4)	▲ 523 (17.8)
† Norway	8%	523 (9.0)	▲ 589 (6.1)	549 (10.0)	570 (6.2)	511 (7.0)	▲ 545 (4.4)
[2] Russian Federation	2%	507 (12.3)	▲ 563 (7.4)	519 (12.9)	▲ 575 (7.7)	501 (14.8)	▲ 555 (7.5)
Sweden	16%	517 (4.4)	▲ 586 (4.6)	551 (4.7)	▲ 579 (4.8)	507 (5.4)	▲ 529 (5.8)
Switzerland	14%	444 (3.5)	▲ 519 (5.3)	452 (4.5)	▲ 507 (7.1)	480 (5.7)	▲ 538 (4.3)
Countries Not Satisfying Guidelines for Sample Participation Rates							
Australia	13%	474 (6.8)	▲ 524 (7.8)	488 (8.3)	525 (6.7)	503 (6.2)	▲ 524 (5.0)
[2] Austria	33%	399 (6.3)	▲ 459 (6.6)	409 (6.9)	▲ 468 (9.1)	420 (6.8)	▲ 485 (8.0)
United States	14%	393 (2.8)	▲ 446 (3.5)	409 (3.6)	▲ 430 (3.5)	474 (2.7)	480 (4.2)
Countries With Unapproved Sampling Procedures and Low Participation Rates							
Denmark	3%	483 (10.2)	▲ 540 (5.5)	498 (7.8)	515 (4.5)	487 (9.6)	517 (5.3)
Slovenia	39%	487 (21.7)	▲ 576 (17.5)	470 (13.8)	▲ 522 (16.6)	470 (18.7)	538 (13.1)
International Avg.		466 (2.6)	▲ 524 (2.2)	483 (2.3)	▲ 514 (2.2)	479 (2.7)	▲ 516 (2.0)

▲ = Difference from other gender statistically significant at .05 level, adjusted for multiple comparisons

*See Mullis and others, 1998 Appendix A for characteristics of the students sampled.

† Met guidelines for sample participation rates only after replacement schools were included (see Mullis and others, 1998 Appendix B for details).

1 National Desired Population does not cover all of International Desired Population (see Mullis and others, 1998 Table B.4).

2 National Defined Population covers less than 90 percent of National Desired Population (see Mullis and others, 1998 Table B.4).

( ) Standard errors appear in parentheses. Because results are rounded to the nearest whole number, some totals may appear inconsistent.

Because population coverage falls below 65%, Latvia is annotated LSS for Latvian Speaking Schools only.

Exhibit 19 provides information on gender differences for each country on each physics content area scale, all favoring males rather than females. The international average for males was significantly higher than the average for females on each of the content area scales, with the greatest differences in Mechanics followed by Wave Phenomena.

For AP Physics students, the average performance for males was significantly higher in three of five content areas: Mechanics, Electricity and Magnetism, and Wave Phenomena. The gen-

Exhibit 19
(Continued)

Country	PTCI	Physics Content Areas Average Achievement Scale Scores			
		Wave Phenomena (10 items)		Modern Physics: Particle, Quantum and Astrophysics, and Relativity (14 items)	
		Females	Males	Females	Males
■ AP Physics Students		490 (6.6)	▲ 527 (6.5)	524 (6.9)	541 (6.5)
Canada	14%	476 (6.4)	497 (4.3)	471 (5.1)	▲ 513 (6.0)
[2] Cyprus	9%	486 (8.4)	519 (10.4)	411 (9.9)	450 (7.7)
Czech Republic	11%	419 (4.9)	▲ 491 (7.2)	425 (4.6)	▲ 498 (6.9)
France	20%	448 (4.6)	▲ 475 (5.6)	457 (4.1)	▲ 485 (4.3)
† Germany	8%	485 (10.1)	▲ 551 (12.7)	508 (13.5)	▲ 561 (15.3)
† Greece	10%	444 (7.2)	457 (7.4)	426 (5.7)	▲ 456 (6.4)
[1] Latvia (LSS)	3%	480 (16.2)	▲ 515 (17.3)	470 (20.8)	▲ 505 (16.6)
† Norway	8%	519 (10.2)	▲ 575 (4.9)	549 (9.9)	▲ 585 (5.0)
[2] Russian Federation	2%	487 (12.4)	▲ 539 (7.9)	520 (13.9)	▲ 561 (7.9)
Sweden	16%	528 (5.9)	▲ 576 (6.1)	538 (6.2)	▲ 570 (3.3)
Switzerland	14%	460 (4.4)	▲ 533 (4.8)	457 (4.4)	▲ 519 (5.8)
Countries Not Satisfying Guidelines for Sample Participation Rates					
Australia	13%	498 (7.2)	▲ 529 (9.0)	497 (7.8)	▲ 533 (6.7)
[2] Austria	33%	444 (9.7)	▲ 506 (7.3)	465 (6.1)	▲ 505 (9.9)
United States	14%	442 (3.0)	▲ 460 (2.6)	446 (2.3)	▲ 466 (3.6)
Countries With Unapproved Sampling Procedures and Low Participation Rates					
Denmark	3%	493 (10.0)	▲ 547 (6.3)	529 (7.4)	546 (6.0)
Slovenia	39%	446 (13.4)	▲ 538 (11.9)	458 (14.1)	▲ 528 (18.7)
International Avg.		472 (2.3)	▲ 519 (2.2)	477 (2.4)	▲ 518 (2.3)

▲ = Difference from other gender statistically significant at .05 level, adjusted for multiple comparisons

der gap for these AP Physics students was smallest in Heat (16 scale score points) and largest in Mechanics and Electricity and Magnetism (44 and 43 scale score points, respectively). In the United States, the average performance of males was significantly higher in four of five content areas: Mechanics, Electricity and Magnetism, Wave Phenomena, and Modern Physics. In these four areas, the gender gap for these United States students was smallest in Wave Phenomena (18 scale score points) and largest in Mechanics (53 scale score points).

Five countries showed significant gender differences in all five content areas: Czech Republic, the Russian Federation, Sweden, Switzerland, and Austria. Other countries showing significant gender differences in achievement in only one or two content areas included Canada, Cyprus, Greece, and Denmark. All countries exhibited significant gender differences in at least one content area.

How Does Calculator Use Relate to the Performance on the TIMSS Physics Test?

Exhibit 20 summarizes the students' reports on how frequently they used a calculator during the testing session. As presented in the exhibit, during the TIMSS physics testing session, 21% of students reported they "Did Not Use a Calculator," 57% reported using a calculator "Very Little" (less than five questions), 20% reported using a calculator "Somewhat" (five to ten questions) and only 2% reported using a calculator "Quite a Lot" (more than ten questions).

In every country except Greece, most students reported using a calculator at least "Somewhat" on the TIMSS Physics test. In Greece, 75% of students reported they did not use a calculator at all. Additionally, in Austria, Latvia, and the Russian Federation more than one-third of the students reported not using a calculator at all. This lack of calculator usage is sharply contrasted by the AP Physics students where very few students reported not using a calculator at all (13%). In all but three countries (Australia, France, and Greece), there appears to be a consistent relationship between physics achievement and calculator use, with achievement increasing as calculator use increased. It is noted that in all countries those students reporting not using a calculator on the TIMSS test performed worse than those students reporting use of any level.

Exhibit 20: Physics Students' Reports on the Frequency of Calculator Use During the TIMSS Physics Test – Final Year of Secondary School*

Country	Did Not Use a Calculator		Used a Calculator Very Little (<5 Questions)		Used a Calculator Somewhat (5-10 Questions)		Used a Calculator Quite a Lot (>10 Questions)	
	Percent of Students	Average Achievement	Percent of Students	Average Achievement	Percent of Students	Average Achievement	Percent of Students	Average Achievement
■ AP Calculus Students	13 (1.6)	491 (10.1)	63 (1.9)	528 (9.5)	23 (1.7)	549 (10.0)	2 (0.5)	~ ~
Australia	9 (1.7)	448 (12.3)	66 (2.3)	528 (6.2)	23 (1.9)	514 (10.0)	2 (0.8)	~ ~
Austria	34 (2.7)	421 (8.3)	49 (2.3)	440 (6.8)	15 (1.6)	456 (15.0)	1 (0.4)	~ ~
Canada	10 (1.6)	451 (10.3)	61 (1.8)	479 (3.8)	27 (1.6)	507 (7.4)	3 (0.4)	548 (19.9)
Cyprus	23 (2.5)	476 (10.9)	60 (2.6)	500 (6.4)	15 (1.9)	510 (17.5)	2 (0.8)	~ ~
Czech Republic	18 (1.8)	425 (11.8)	62 (3.1)	449 (5.3)	19 (2.1)	485 (11.0)	1 (0.4)	~ ~
Denmark	11 (1.4)	512 (9.8)	66 (1.8)	537 (5.0)	21 (1.8)	541 (9.4)	2 (0.6)	~ ~
France	17 (1.4)	447 (4.6)	63 (1.5)	471 (4.5)	18 (1.7)	471 (7.4)	1 (0.4)	~ ~
Germany	17 (2.1)	475 (19.2)	64 (2.5)	528 (12.1)	18 (2.2)	546 (12.7)	1 (0.5)	~ ~
Greece	75 (2.8)	475 (6.0)	22 (2.7)	530 (9.6)	3 (0.9)	494 (32.1)	1 (0.6)	~ ~
Latvia (LSS)	38 (4.5)	471 (24.2)	49 (3.3)	490 (23.0)	11 (2.1)	514 (15.6)	1 (0.3)	~ ~
Norway	4 (0.8)	558 (17.0)	56 (1.8)	572 (7.7)	37 (1.8)	597 (6.8)	3 (0.6)	616 (18.1)
Russian Federation	36 (2.8)	543 (12.1)	49 (2.2)	551 (11.9)	14 (1.3)	570 (15.5)	1 (0.4)	~ ~
Slovenia	17 (2.2)	476 (15.2)	65 (2.4)	532 (16.6)	16 (1.5)	562 (17.4)	2 (1.0)	~ ~
Sweden	3 (0.6)	526 (26.5)	53 (2.6)	562 (5.1)	38 (2.5)	588 (5.8)	5 (0.7)	611 (16.6)
Switzerland	13 (1.5)	461 (8.8)	62 (1.6)	493 (3.9)	23 (1.3)	496 (7.6)	2 (0.4)	~ ~
United States	19 (1.3)	391 (4.0)	64 (1.4)	427 (3.5)	16 (1.1)	443 (4.8)	1 (0.3)	~ ~
International Avg.	21 (0.5)	472 (3.4)	57 (0.6)	506 (2.4)	20 (0.4)	518 (3.5)	2 (0.1)	~ ~

*See Mullis and others, 1998 Appendix A for characteristics of the students sampled.

Countries shown in italics did not satisfy one or more guidelines for sample participation rates or student sampling (see Mullis and others; 1998 Figure B.6).

Because population coverage falls below 65%, Latvia is annotated LSS for Latvian Speaking Schools only.

Countries shown in italics did not satisfy one or more guidelines for sample participation (see Mullis and others, 1998 Figure B.6).

( ) Standard errors appear in parentheses. Because results are rounded to the nearest whole number, some totals may appear inconsistent.

A tilde (~) indicates insufficient data to report achievement.

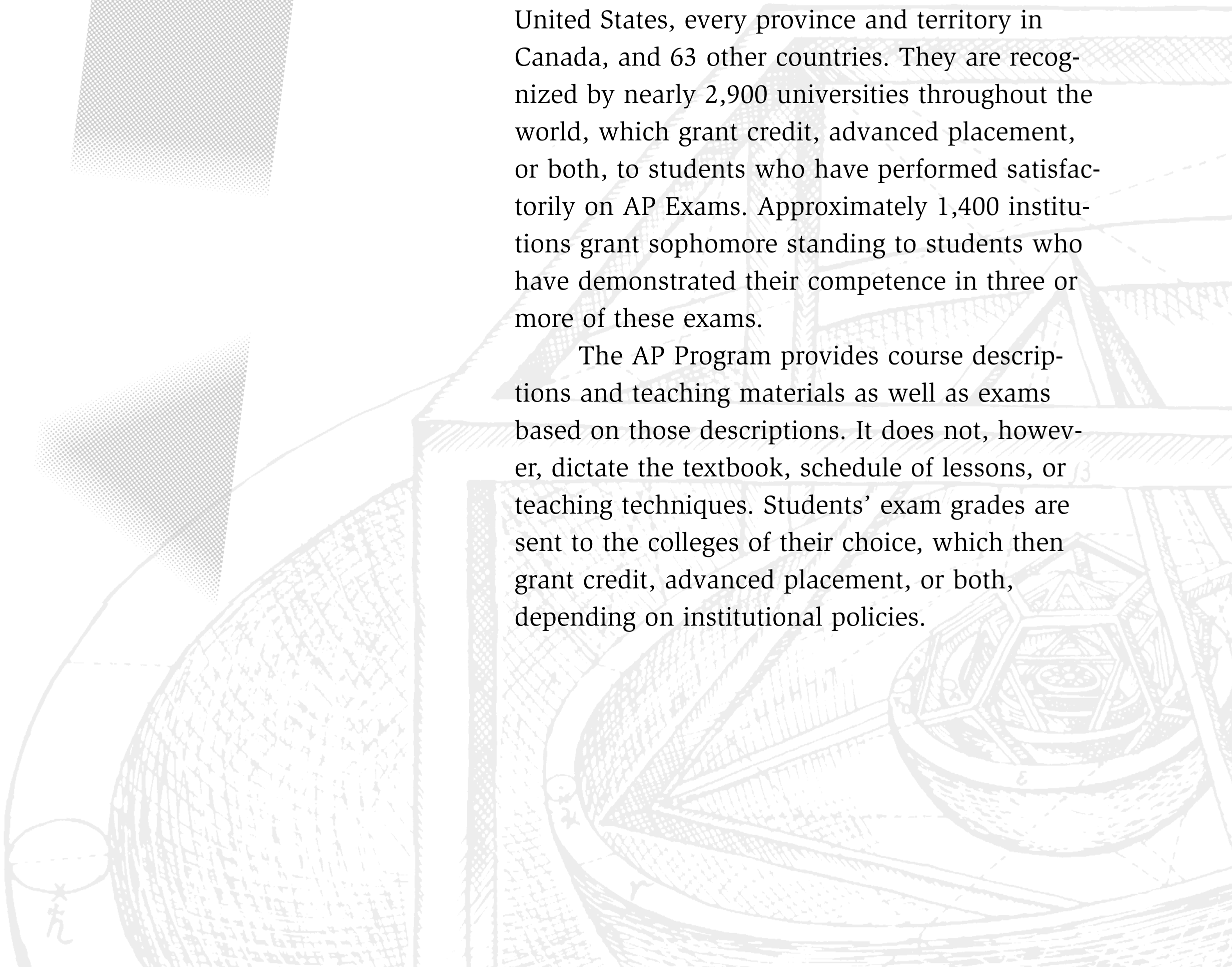
Appendix A

The AP® Program

The College Board Advanced Placement (AP®) Program® consists of 35 college-level courses and exams in 19 disciplines that can be taken by students while still in secondary school. Its exceptional reputation is made possible by the close cooperation of secondary schools, colleges, and the College Board. Students report that they enjoy the challenge of the Program, high school faculty find that AP courses greatly enhance students' confidence and academic interest, and college faculty find that these students are far better prepared for serious academic work.

AP courses and exams are offered in more than 13,500 high schools in every state in the United States, every province and territory in Canada, and 63 other countries. They are recognized by nearly 2,900 universities throughout the world, which grant credit, advanced placement, or both, to students who have performed satisfactorily on AP Exams. Approximately 1,400 institutions grant sophomore standing to students who have demonstrated their competence in three or more of these exams.

The AP Program provides course descriptions and teaching materials as well as exams based on those descriptions. It does not, however, dictate the textbook, schedule of lessons, or teaching techniques. Students' exam grades are sent to the colleges of their choice, which then grant credit, advanced placement, or both, depending on institutional policies.



Further information about the AP Program can be obtained from any regional office of the College Board, the national office in New York, or the College Board’s website: www.collegeboard.com.

The Course Descriptions

A committee made up of college faculty and AP teachers develops each course; members of these Development Committees are appointed by the College Board and serve for overlapping terms. Course Descriptions, end-of-course examinations, and sets of supporting materials are available for each of the 35 AP courses.

The Course Descriptions are regularly distributed to participating schools and colleges and may be purchased or downloaded free of charge from the College Board website. In most subjects, they are supplemented by a Teacher’s Guide, a released exam (which includes a description of how the exam was scored), and samples of previously administered free-response questions. While these publications have been designed primarily for educators, students preparing for the exams independently can benefit from using them.

The AP Exams

AP Exams are offered throughout the world. They are administered at participating schools or at multischool centers. Any school may participate; it need only file the AP Participation Form sent to all high schools every fall. Except for Studio Art – which consists of a portfolio assessment – all exams contain a free-response section (either essay or problem-solving) and another section consisting of multiple-choice questions.

AP Calculus: Calculus AB and Calculus BC

An Advanced Placement (AP) course in calculus consists of a full high school academic year of work that is comparable to calculus courses in colleges and universities. It is expected that students who take an AP course in calculus will seek college credit, college placement, or both, from institutions of higher learning. The AP Program includes specifications for two calculus courses and the examination for each course. The two courses and the two corresponding examinations are designated as Calculus AB and Calculus BC. The aim of an AP course in calculus should be to develop the students’ abilities to do the following:

- Students should be able to work with functions represented in a variety of ways: graphical, numerical, analytical, or verbal. They should understand the connections among these representations.

- Students should understand the meaning of the derivative in terms of a rate of change and local linear approximation and should be able to use derivatives to solve a variety of problems.

- Students should understand the meaning of the definite integral both as a limit of Riemann sums and as the net accumulation of a rate of change and should be able to use integrals to solve a variety of problems.

- Students should understand the relationship between the derivative and the definite integral as expressed in both parts of the Fundamental Theorem of Calculus.

- Students should be able to communicate mathematics both orally and in well-written sentences and should be able to explain solutions to problems.

- Students should be able to model a written description of a physical situation with a function, a differential equation, or an integral.

- Students should be able to use technology to help solve problems, experiment, interpret results, and verify conclusions.

- Students should be able to determine the reasonableness of solutions, including sign, size, relative accuracy, and units of measurement.

- Students should develop an appreciation of calculus as a coherent body of knowledge and as a human accomplishment.

Calculus AB can be offered by schools that are able to complete all the prerequisites – four years of secondary mathematics designed for college-bound students in which they study algebra, geometry, trigonometry, analytic geometry, and elementary functions. Calculus AB is designed to be taught over a full high school academic year. It is possible to spend some time on elementary functions and still cover the Calculus AB curriculum within a year.

Calculus BC can be offered by schools that are able to complete all the prerequisites – four years of secondary mathematics designed for college-bound students in which they study algebra, geometry, trigonometry, analytic geometry, and elementary functions. Calculus BC is a full-year course in the calculus of functions of a single variable. It includes all topics covered in Calculus AB plus additional topics, but both courses are intended to be equally challenging and demanding; they require a similar depth of understanding of common topics.

Both courses described here represent college-level mathematics for which most colleges grant advanced placement and credit. Most colleges and universities offer a sequence of several courses in calculus, and entering students are placed within this sequence according to the extent of their preparation, as measured by the results of an AP Examination or other criteria. Appropriate credit and placement are granted by each college or university in accordance with institutional policies. The content of Calculus BC is designed to qualify the student for placement and credit in a course that is one course beyond that granted for Calculus AB. Individual colleges often provide descriptions of their specific AP policies in the catalogs.

The determination of whether Calculus AB or Calculus BC is most appropriate for a particular school depends on local conditions and resources: school size, curriculum, the preparation of teachers, and the interest of students, teachers and administrators.

Calculus AB and Calculus BC are primarily concerned with developing the students' understanding of the concepts of calculus and providing experience with its methods and applications. The courses emphasize a multi-representational approach to calculus, with concepts, results, and problems being expressed geometrically, numerically, analytically, and verbally. The connections among these representations also are important.

Calculus BC is an extension of Calculus AB rather than an enhancement; common topics require a similar depth of understanding. Both courses are intended to be challenging and demanding. Broad concepts and widely applicable methods are emphasized. The focus of the courses is neither manipulation nor memorization of an extensive taxonomy of functions, curves, theorems, or problem types. Thus, although facility with manipulation and computational competence are important outcomes, they are not the primary cores of these courses.

Technology can be used regularly by students and teachers to reinforce the relationships among the multiple representations of functions, to confirm written work, to implement experimentation, and to assist in interpreting results. Through the use of unifying themes of derivatives, integrals, limits, approximation, and the applications and modeling, the course becomes a cohesive whole rather than a collection of unrelated topics.

AP Physics: Physics B and Physics C

Three AP Examinations in Physics, identified as Physics B, Physics C: Mechanics, and Physics C: Electricity and Magnetism, are offered. These examinations are designed to test student achievement in the Physics B and Physics C courses. These courses are intended to be representative of courses commonly offered in American colleges and universities, but they do not necessarily correspond precisely to courses at any particular institution. The aim of an AP secondary school course in physics should be to develop the students' abilities to do the following:

- Read, understand, and interpret physical information – verbal, mathematical, and graphical.

- Describe and explain the sequence of steps in the analysis of a particular physical phenomenon or problem; that is,

  - » Describe the idealized model to be used in the analysis, including simplifying assumptions where necessary,
  - » State the principles or definitions that are applicable,
  - » Specify relevant limitations on applications of these principles,
  - » Carry out and describe the steps of the analysis, verbally or mathematically, and
  - » Interpret the results or conclusions, including discussion of particular cases of special interest.
- Use basic mathematical reasoning – arithmetic, algebraic, geometric, trigonometric, or calculus, where appropriate – in a physical situation or problem.
- Perform experiments and interpret the results of observations, including making an assessment of experimental uncertainties.

The Physics B course provides a systematic introduction to the main principles of physics and emphasizes the development of problem-solving ability. It is assumed that the student is familiar with algebra and trigonometry; calculus is seldom used, although some theoretical developments may use basic concepts of calculus. In most colleges this is a one-year terminal course with a laboratory component and is not the usual preparation for more advanced physics and engineering courses. However, the B course often provides a foundation in physics for students in the life sciences, pre-medicine, and some applied sciences, as well as other fields not directly related to science.

The Physics C courses ordinarily form the first part of the college sequence that serves as the foundation in physics for students majoring in the physical sciences or engineering. The sequence is parallel to or preceded by mathematics courses that include calculus. Methods of calculus are used wherever appropriate in formulating physical principles and in applying them to physical problems. The sequence is more intensive and analytic than that in the B course. Strong emphasis is placed on solving a variety of challenging problems, some requiring calculus. The subject matter of the two C courses is mechanics, and electricity and magnetism, with many AP students taking the two courses in sequence in a single school year. The C courses are the first part of a sequence that is sometimes a very intensive one-year course in college but that usually extends over one and one-half to two years with a laboratory component.

In the AP Physics Examinations, multiple-choice and free-response questions are used to determine how well these goals have been achieved by the student either in a conventional course or through independent study. Many colleges use the AP grade as the basis for placement and credit decisions.

Appendix B

Supporting Exhibits

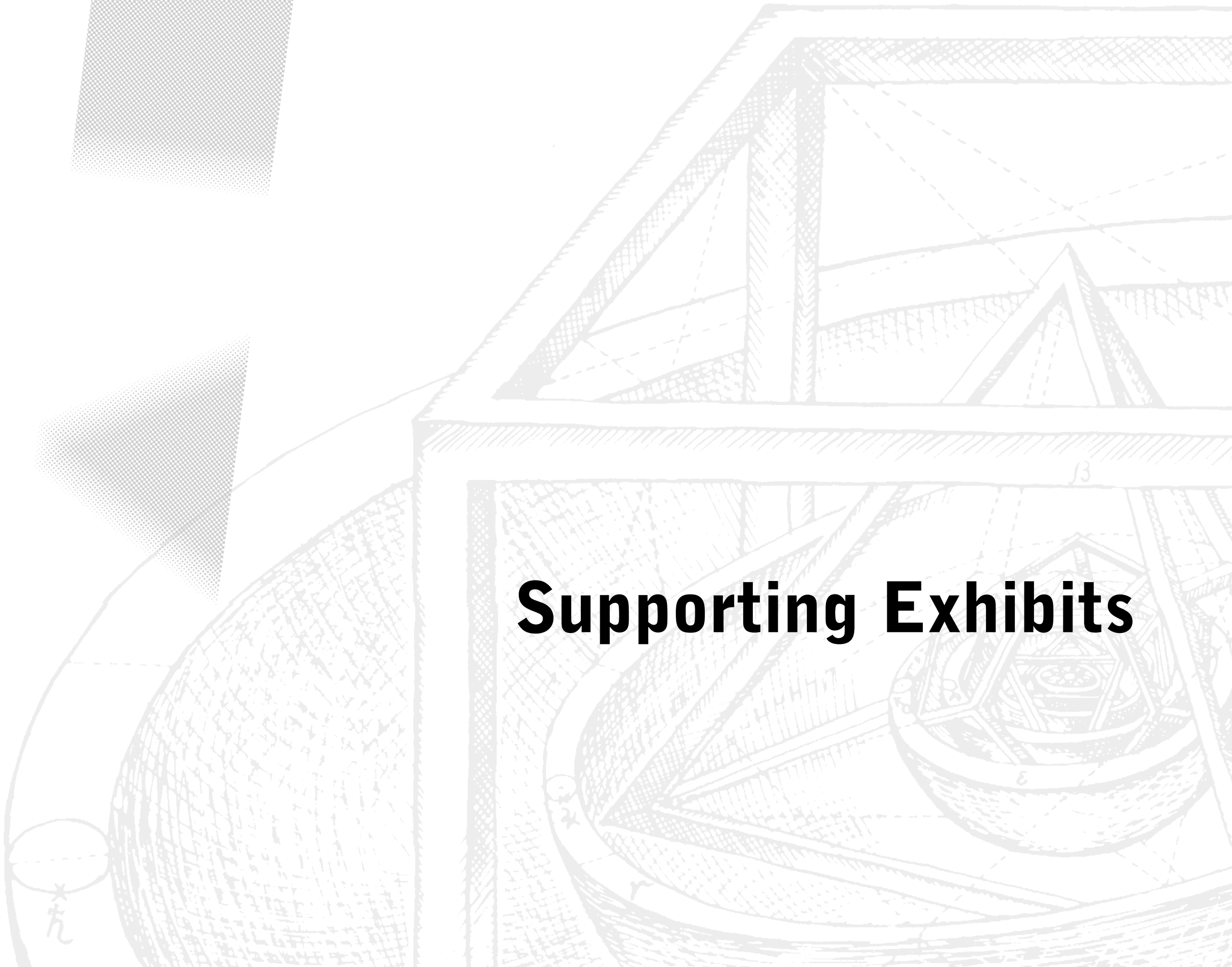


Exhibit B.1: Percentiles of Achievement in Advanced Mathematics – Final Year of Secondary School*

Country	5th Percentile	25th Percentile	50th Percentile	75th Percentile	95th Percentile
■ AP Calculus Students	445 (12.4)	521 (6.3)	572 (4.5)	626 (3.4)	703 (9.9)
Australia	337 (30.1)	456 (17.6)	530 (9.1)	597 (10.4)	692 (21.1)
Austria	283 (15.2)	379 (11.3)	443 (7.9)	497 (8.8)	577 (16.4)
Canada	352 (7.1)	443 (5.4)	508 (4.8)	576 (7.2)	676 (10.1)
Cyprus	371 (23.0)	465 (5.7)	523 (10.4)	574 (5.2)	651 (15.8)
Czech Republic	320 (12.7)	399 (9.2)	454 (10.4)	524 (15.6)	665 (20.2)
Denmark	403 (5.6)	474 (3.8)	523 (2.3)	572 (4.8)	643 (6.9)
France	439 (5.5)	511 (5.1)	558 (5.5)	603 (6.4)	673 (8.3)
Germany	328 (9.3)	408 (8.0)	463 (5.7)	522 (5.6)	605 (6.9)
Greece	321 (35.1)	454 (11.6)	521 (6.4)	585 (5.1)	668 (12.7)
Italy	314 (14.9)	419 (13.4)	477 (10.3)	534 (8.3)	622 (22.7)
Lithuania	388 (12.2)	461 (5.5)	512 (3.6)	567 (3.3)	666 (16.9)
Russian Federation	360 (9.3)	465 (9.3)	539 (12.7)	618 (9.4)	730 (22.4)
Slovenia	330 (10.2)	408 (9.5)	473 (10.1)	537 (8.5)	630 (20.4)
Sweden	375 (7.9)	458 (10.5)	513 (11.4)	568 (7.0)	653 (13.6)
Switzerland	401 (5.6)	473 (6.2)	525 (7.9)	587 (5.9)	691 (3.4)
United States	292 (3.8)	375 (7.1)	437 (6.4)	504 (6.1)	609 (8.9)

* See Mullis and others, 1998 Appendix A for characteristics of the students sampled.

( ) Standard errors appear in parentheses.

Countries shown in italics did not satisfy one or more guidelines for sample participation rates or student sampling (see Mullis and others, 1998 Figure B.6)

Exhibit B.2: Means and Standard Deviations of Achievement in Advanced Mathematics– Final Year of Secondary School*

Country	Overall		Females		Males	
	Average Achievement	Standard Deviation	Average Achievement	Standard Deviation	Average Achievement	Standard Deviation
■ AP Calculus Students	573 (4.4)	79 (2.8)	562 (3.8)	72 (3.0)	581 (5.9)	83 (4.0)
Australia	525 (11.6)	109 (7.9)	517 (15.1)	110 (9.3)	531 (11.4)	108 (9.0)
Austria	436 (7.2)	91 (5.5)	406 (8.6)	87 (6.6)	486 (7.3)	76 (5.4)
Canada	509 (4.3)	98 (2.4)	489 (4.4)	89 (2.7)	528 (6.4)	103 (2.9)
Cyprus	518 (4.3)	85 (3.0)	509 (6.4)	77 (4.9)	524 (4.4)	90 (3.9)
Czech Republic	469 (11.2)	106 (9.3)	432 (8.9)	89 (6.4)	524 (13.0)	106 (12.0)
Denmark	522 (3.4)	73 (1.9)	510 (4.6)	68 (3.4)	529 (4.4)	76 (2.3)
France	557 (3.9)	70 (2.1)	543 (5.1)	67 (2.9)	567 (5.1)	70 (2.6)
Germany	465 (5.6)	85 (3.4)	452 (6.6)	81 (3.9)	484 (6.5)	86 (4.1)
Greece	513 (6.0)	105 (6.0)	505 (10.2)	88 (8.5)	516 (6.6)	111 (7.5)
Italy	474 (9.6)	95 (8.1)	460 (14.1)	95 (13.1)	484 (10.6)	94 (8.7)
Lithuania	516 (2.6)	85 (3.2)	490 (5.6)	78 (6.8)	542 (3.7)	84 (3.8)
Russian Federation	542 (9.2)	112 (5.6)	515 (10.2)	106 (8.0)	568 (9.7)	111 (4.4)
Slovenia	475 (9.2)	94 (3.8)	464 (11.0)	89 (3.5)	484 (11.5)	97 (5.4)
Sweden	512 (4.4)	86 (2.9)	496 (5.2)	78 (4.5)	519 (5.9)	88 (3.6)
Switzerland	533 (5.0)	90 (2.7)	503 (5.7)	77 (4.9)	559 (5.6)	93 (3.9)
United States	442 (5.9)	98 (4.1)	426 (7.1)	98 (5.6)	457 (7.8)	96 (4.8)

* See Mullis and others, 1998 Appendix A for characteristics of the students sampled.

( ) Standard errors appear in parentheses.

Countries shown in italics did not satisfy one or more guidelines for sample participation rates or student sampling (see Mullis and others, 1998 Figure B.6)

Exhibit B.3: Percentiles of Achievement in Physics – Final Year of Secondary School*

Country	5th Percentile	25th Percentile	50th Percentile	75th Percentile	95th Percentile
■ AP Physics Students	366 (15.1)	464 (9.0)	527 (5.7)	596 (8.7)	693 (12.8)
Australia	386 (11.8)	461 (3.3)	517 (6.6)	570 (8.5)	656 (11.9)
Austria	306 (11.9)	379 (11.3)	427 (5.9)	486 (10.1)	581 (22.3)
Canada	346 (5.1)	429 (2.9)	482 (4.4)	539 (7.3)	633 (14.3)
Cyprus	325 (8.0)	434 (10.9)	487 (4.9)	551 (9.0)	681 (28.8)
Czech Republic	337 (4.5)	397 (6.2)	440 (6.6)	493 (12.3)	605 (29.5)
Denmark	397 (8.4)	478 (4.3)	535 (5.9)	588 (6.1)	677 (15.2)
France	358 (9.4)	423 (6.8)	465 (4.1)	509 (3.1)	574 (8.3)
Germany	374 (13.2)	458 (16.2)	519 (12.0)	580 (19.1)	688 (10.1)
Greece	333 (18.9)	431 (5.7)	495 (7.7)	545 (6.3)	619 (8.2)
Latvia (LSS)	348 (12.2)	418 (15.7)	474 (19.2)	540 (36.5)	687 (31.5)
Norway	432 (6.3)	517 (11.1)	578 (6.3)	646 (7.2)	727 (6.1)
Russian Federation	368 (18.2)	468 (15.7)	544 (12.6)	619 (16.5)	722 (21.2)
Slovenia	332 (11.3)	457 (15.4)	528 (21.2)	598 (14.1)	689 (36.3)
Sweden	422 (12.2)	511 (8.9)	574 (6.6)	634 (6.6)	725 (6.7)
Switzerland	353 (20.6)	430 (7.6)	479 (4.7)	540 (5.2)	648 (9.9)
United States	331 (4.7)	384 (4.0)	420 (4.2)	458 (6.5)	520 (6.6)

* See Mullis and others, 1998 Appendix A for characteristics of the students sampled.

( ) Standard errors appear in parentheses.

Countries shown in italics did not satisfy one or more guidelines for sample participation rates or student sampling (see Mullis and others, 1998 Figure B.6)

Exhibit B.4: Means and Standard Deviations of Achievement in Physics – Final Year of Secondary School*

Country	Overall		Females		Males	
	Average Achievement	Standard Deviation	Average Achievement	Standard Deviation	Average Achievement	Standard Deviation
■ AP Physics Students	529 (7.7)	102 (7.3)	503 (8.8)	94 (6.6)	543 (8.5)	100 (8.5)
Australia	518 (6.2)	82 (3.6)	490 (8.4)	75 (5.3)	532 (6.7)	82 (5.6)
Austria	435 (6.4)	83 (4.6)	408 (7.4)	71 (5.9)	479 (8.1)	82 (5.7)
Canada	485 (3.3)	87 (3.0)	459 (6.3)	75 (3.9)	506 (6.0)	90 (4.2)
Cyprus	494 (5.8)	105 (5.3)	470 (7.1)	96 (7.9)	509 (8.9)	108 (7.9)
Czech Republic	451 (6.2)	82 (5.9)	419 (3.9)	63 (5.1)	503 (8.8)	83 (5.4)
Denmark	534 (4.2)	85 (3.9)	500 (8.1)	74 (6.8)	542 (5.2)	87 (4.4)
France	466 (3.8)	66 (3.1)	450 (5.6)	61 (3.2)	478 (4.2)	67 (4.4)
Germany	522 (11.9)	94 (5.3)	479 (9.1)	80 (5.3)	542 (14.3)	93 (6.9)
Greece	486 (5.6)	87 (3.7)	468 (8.1)	79 (6.9)	495 (6.1)	90 (5.0)
Latvia (LSS)	488 (21.5)	100 (10.6)	467 (22.6)	97 (11.4)	509 (19.0)	99 (11.5)
Norway	581 (6.5)	91 (2.5)	544 (9.3)	88 (4.5)	594 (6.3)	88 (2.5)
Russian Federation	545 (11.6)	110 (5.0)	509 (15.3)	108 (9.1)	575 (9.9)	103 (3.8)
Slovenia	523 (15.5)	109 (8.7)	455 (18.7)	106 (6.4)	546 (16.3)	99 (10.8)
Sweden	573 (3.9)	92 (2.8)	540 (5.3)	78 (4.8)	589 (5.1)	94 (3.7)
Switzerland	488 (3.5)	88 (2.9)	446 (3.6)	69 (2.9)	529 (5.2)	86 (4.0)
United States	423 (3.3)	60 (3.2)	405 (3.1)	53 (1.8)	439 (4.3)	62 (5.0)

* See Mullis and others, 1998 Appendix A for characteristics of the students sampled.

( ) Standard errors appear in parentheses.

Countries shown in italics did not satisfy one or more guidelines for sample participation rates or student sampling (see Mullis and others, 1998 Figure B.6)

Appendix C

TIMSS International Reports

Beaton, A.E., Martin, M.O., Mullis, I.V.S., Gonzalez, E.J., Smith, T.A., and Kelly, D.L. (1996), *Science Achievement in the Middle School Years: IEA's Third International Mathematics and Science Study*, Chestnut Hill, MA: Boston College.

Beaton, A.E., Mullis, I.V.S., Martin, M.O., Gonzalez, E.J., Kelly, D.L., and Smith, T.A. (1996), *Mathematics Achievement in the Middle School Years: IEA's Third International Mathematics and Science Study*, Chestnut Hill, MA: Boston College.

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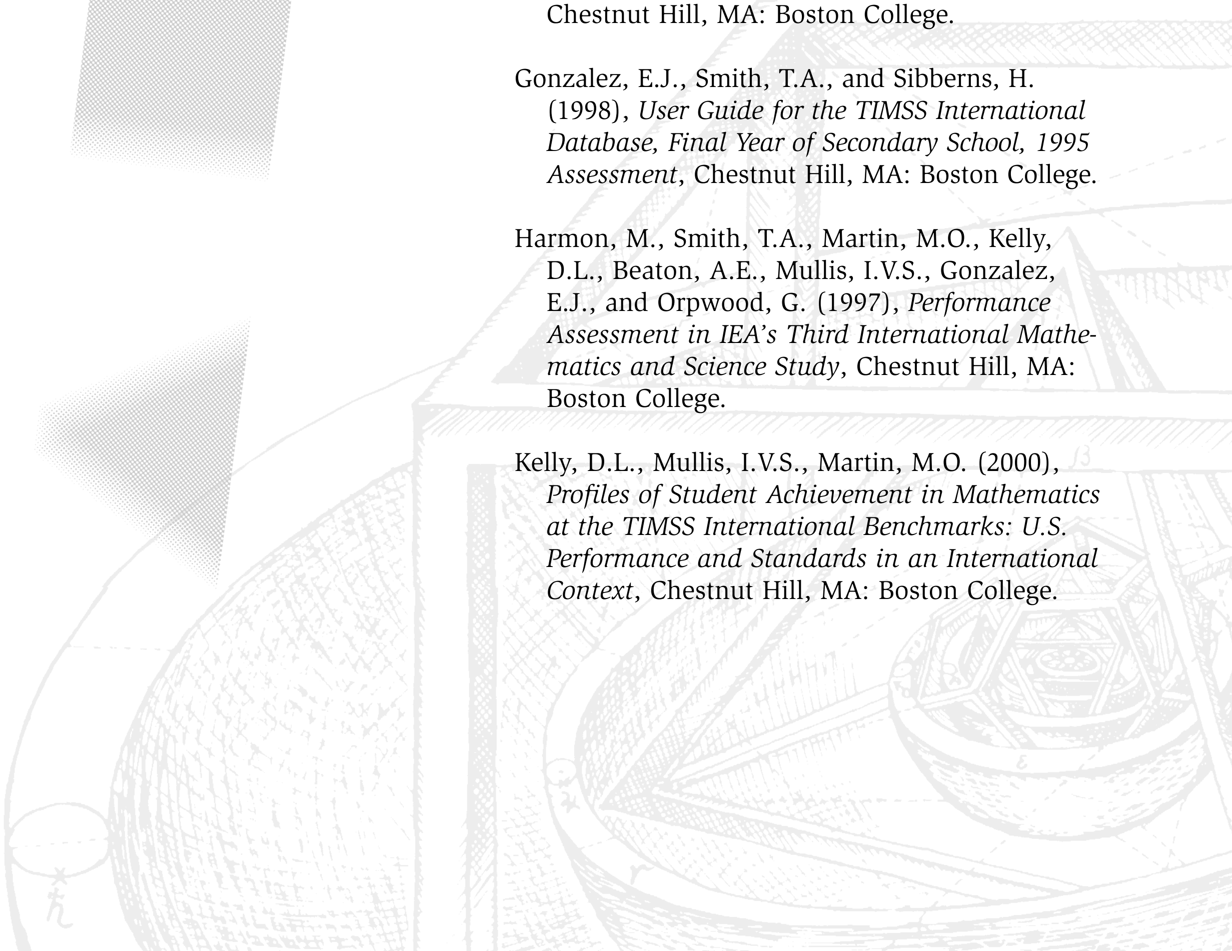
Kelly, D.L., Mullis, I.V.S., Martin, M.O. (2000), *Profiles of Student Achievement in Mathematics at the TIMSS International Benchmarks: U.S. Performance and Standards in an International Context*, Chestnut Hill, MA: Boston College.



Martin, M.O., Mullis, I.V.S., Beaton, A.E., Gonzalez, E.J., Smith, T.A., and Kelly, D.L, (1997) *Science Achievement in the Primary School Years: IEA's Third International Mathematics and Science Study*, Chestnut Hill, MA: Boston College.

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Martin, M.O., Mullis, I.V.S., Gonzalez, E.J., Smith, T.A., and Kelly, D.L., (1999), *School Contexts for Learning and Instruction*, Chestnut Hill, MA: Boston College.

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Mullis, I.V.S., Martin, M.O., Beaton, A.E., Gonzalez, E.J., Kelly, D.L., and Smith T.A., (1998), *Mathematics and Science Achievement in the Final Year of Secondary School*, Chestnut Hill, MA: Boston College.

Mullis, I.V.S., Martin, M.O., Fierros, E.G., Goldberg, A.L., and Stemler, S.E., (2000), *Gender Differences in Achievement*, Chestnut Hill, MA: Boston College.

Mullis, I.V.S., Martin, M.O. Gonzalez, E.J., Gregory, K.D, Smith, T.A., Chrostowski, S.J., Garden, R.A., and O'Connor, K.M. (2000) *TIMSS 1999 International Mathematics Report, Findings from IEA's Repeat of the Third International Mathematics and Science Study at the Eighth Grade*, Chestnut Hill, MA: Boston College.

Smith, T.A., Martin, M.O., Mullis, I.V.S., and Kelly, D.L. (2000). *Profiles of Student Achievement in Science at the TIMSS International Benchmarks: U.S. Performance and Standards in an International Context*, Chestnut Hill, MA: Boston College.