Introduction

This report presents findings from the TIMSS Advanced 2008 assessments of advanced mathematics and physics at the senior secondary school level in 10 countries, and includes a discussion of changes in students' achievement over time in the 5 countries whose students participated in both cycles of the project in 1995 and 2008. (For a list of countries, please see Exhibit 1 in the following section headed, "Countries Participating in TIMSS Advanced 2008.") The report contains considerable information about the contexts for teaching and learning advanced material in mathematics and physics in the participating countries.

Two other volumes, the *TIMSS Advanced 2008 Assessment Frameworks* and the *TIMSS Advanced 2008 Technical Report*, are also available. The *TIMSS Advanced 2008 Assessment Frameworks* describes the advanced mathematics and physics frameworks, respectively, underlying the two assessments as well as the design of the assessments. The *TIMSS Advanced 2008 Technical Report* provides technical documentation about the development and implementation of the assessments. The *TIMSS Advanced 2008 International Database and User Guide* includes the entire international database for both assessments together with proprietary database management and analysis software. The TIMSS Advanced 2008 publications and the database can be found on the TIMSS website (timssandpirls.bc.edu).

Achievement results from a study such as this are influenced by many factors, and the international report is typically complemented by a national report prepared in each country. In their national reports, countries can explore their data in more detail, or examine aspects of particular policy relevant factors in more depth than is possible in the international report.

Background for IEA's TIMSS Advanced 2008 Assessment

TIMSS Advanced 2008 is one in a series of TIMSS assessments designed to provide comparative information about educational achievement across countries as part of a continuing effort to improve the teaching and learning of mathematics and science in elementary and secondary schools internationally. TIMSS (Trends in International Mathematics and Science Study) is a global enterprise, with countries working cooperatively together to examine students' achievement in mathematics and science as well as report on curricular innovations and instructional practices in the participating countries.

TIMSS is a major project of the International Association for the Evaluation of Educational Achievement (IEA), an independent cooperative of national research institutions and government agencies with the mission of providing high quality information on students' achievement outcomes and on the educational contexts in which students achieve. IEA has been conducting cross-national studies of student achievement in a wide range of school subjects since 1959.

The first cycle of TIMSS was conducted in 1995 and examined the teaching and learning of mathematics and science at several grade levels, including a senior secondary school population of students in their last year of secondary school who were studying advanced mathematics or physics to prepare them for further study of mathematics and science at the tertiary level. Twenty countries participated in that study altogether, with 16 countries participating in the advanced mathematics study and a slightly different set of 16 countries participating in the physics study. There was considerable interest in the 1995 TIMSS Advanced project, particularly among educational policy makers, mathematics educators, and science educators. Many viewed the study as an opportunity to "use the world as an educational laboratory," in Torsten Husén's memorable phrase, to learn more about what was educationally feasible with respect to the teaching and learning of mathematics and science in preparing students for their future careers.

In the almost 15 years that have elapsed since that first cycle of TIMSS, there have been regular 4-year iterations of the study at the fourth and eighth grades,[1] but not at the senior secondary level. Over that period, a number of countries and individuals have expressed interest in replicating the 1995 TIMSS assessment of students having taken advanced courses, and a decision was made to conduct TIMSS Advanced 2008, focusing once again on students who were enrolled in the last year of secondary school, and who were specializing in advanced mathematics or physics as part of an academic program.

Taking part in an international study comparing and contrasting the achievement of senior secondary students enrolled in the most advanced programs in mathematics and science that their countries have to offer is an attractive prospect for many educators, researchers, and policy makers. Many believe that the future security and well-being of their societies are strongly linked to the quality and quantity of well educated citizens graduating from their secondary schools,

1 TIMSS 1995, TIMSS 1999, TIMSS 2003, and TIMSS 2007 have been completed, and TIMSS 2011 currently is underway.

particularly those with strong backgrounds and career interests in fields related to mathematics, science, engineering, and technology.

In shaping education policy, every country confronts the challenge of providing a high level of education for all students. As part of this challenge, countries need to consider the issue of at what level and how many specialists they should be preparing in mathematics, science, and engineering. It is important globally for countries to educate students who can teach and pursue careers in a host of crucial medical, social, and industrial fields requiring specialized mathematics or physics knowledge and who are capable of making the kinds of technological discoveries that will improve the quality of life worldwide. To address this need, countries typically offer a variety of specialized programs for their senior secondary students, including programs designed to prepare students for admission to the study of mathematics, science, and related areas at the university or other tertiary levels. Decisions about what constitutes a high level of education or a specialized program, however, differ considerably across countries as do ideas about how many students should or can participate in advanced courses or receive specialist or even "super" specialist training. Across countries, programs in advanced mathematics and physics vary widely in terms of the proportion of the age cohort of students enrolled in them, in the depth and sophistication of the subject matter content included, and in their pedagogical and administrative contexts.

As attractive as the prospect of participating in an international comparative study at this level might be, there are significant obstacles to be overcome. At the elementary or lower secondary school levels, it is generally the case that virtually all of the children in the relevant age cohort in a given country are enrolled in school and studying more or less the same content. Also, at least as far as mathematics and science are concerned, there is a great deal of curricular commonality across countries. So reaching agreement on the content to be assessed is quite feasible, although still a challenging task.

The challenge is considerably more difficult at the senior secondary level. By that time, a significant proportion of the age cohort may no longer be in school, either because students who were registered in certain programs have completed their program at an earlier exit point in the system (e.g., after Grade 10 in some countries), or they have dropped out of school. Also, the number of program and curricular choices available to students varies significantly across countries at the senior secondary level. This means that the percentage of students who elect to specialize in advanced mathematics or physics varies greatly across countries, as does the content of the curriculum they are taught. In addition, there are complications inherent in the assessment of older students. In many countries, students in their final year of secondary school, and especially those in advanced programs, are facing the pressure associated with high-stakes, national, end-of-school-year examinations, particularly when the TIMSS Advanced 2008 data collection was scheduled in the last quarter of the school year, at about the same time as those examinations. Also, some countries have difficulty meeting the high standards that TIMSS has in place regarding student and school participation rates, and it is well known that as students get older and more independent, it is more difficult to get them to participate voluntarily in such a project.

In looking at the results for TIMSS Advanced 2008, the additional sources of variation across countries complicate the interpretation of the outcome data; however, considerable effort has been made to provide detailed descriptions about the educational programs for learning advanced mathematics and physics in each of the participating countries and to fully document educational and demographic information about the students assessed. Also, every effort was made to ensure that the assessments would provide fair comparisons of student achievement in advanced mathematics and physics. The frameworks for the content to be assessed and the assessment items were developed through a collaborative process involving representatives from the participating countries. The data provide a rich source of information for those interested in examining what higher learning is possible. If, for example, Country A offers a highly enriched program in advanced mathematics to a significant percentage of its age cohort, and those students achieve at comparatively high levels on an international assessment, what implications do such results have for educators, researchers, and policy makers in other countries?

The TIMSS Curriculum Model

The purpose of the TIMSS international endeavor as a whole is to help improve teaching and learning in mathematics and science, and to this end the project is designed specifically to provide important, policy-relevant information that can be used to evaluate the success of educational systems. In addition to providing information about trends in academic achievement, TIMSS collects a rich array of background information to provide comparative perspectives on the achievement trends in the context of different educational systems, school organizational approaches, and instructional practices.

Because every country has national or regional curriculum goals and expends significant resources on developing and implementing those goals, the information that TIMSS collects about the success of curriculum implementation is extremely valuable for participating countries. TIMSS uses the curriculum, broadly defined, as the major organizing concept in considering how educational opportunities are provided to students, and the factors that influence how students use these opportunities. The TIMSS curriculum model has three aspects:

the intended curriculum, the implemented curriculum, and the achieved curriculum. These represent, respectively, the mathematics and science curriculum that the country (or regional entity) intends for students to learn and policies that have been developed to facilitate this learning; what is actually taught in classrooms, who teaches it, and how it is taught; and, finally, what it is that students have learned, and what they think about these subjects.

While the results on the TIMSS Advanced 2008 achievement tests in advanced mathematics and physics describe students' learning in the participating countries, responses to a series of background questionnaires provide extensive information about the structure and content of the intended curriculum, the preparations and experience of teachers, the mathematics and physics actually taught, the instructional approaches used, the organization and resources of schools and classrooms, and the experiences and attitudes of students in the schools. An important characteristic of IEA studies, notably including TIMSS, is that they are designed on the basis of a representative sample of intact classrooms within schools in the participating countries. As a result, student outcomes can be examined in the light of curricular and pedagogical variables in ways that would not be possible in the case of studies based on random selections of students within schools.

Countries participating in TIMSS Advanced 2008 completed questionnaires about their national education systems and situations, providing descriptions of their official curricula and identifying the TIMSS Advanced topics that were specified in the intended curricula. Data about the instructional methods used to implement the curriculum were provided by teachers and principals of the assessed students and by the students themselves. Corresponding to the information about the intended curriculum, teachers provided information about each of the TIMSS topics taught to the students.

The students provided information about their home and classroom experiences, and their teachers and schools provided information about instructional practices, school resources, and the school climate for learning.

Conducting TIMSS Advanced 2008

IEA has delegated responsibility for the overall direction and management of TIMSS Advanced to the TIMSS & PIRLS International Study Center at Boston College, which also conducts IEA's TIMSS and PIRLS projects. Since first being conducted in 1995, TIMSS has reported every four years on the achievement of fourth and eighth grade students in countries all around the world. TIMSS 2011, the fifth in the series of TIMSS assessments, is currently underway and is expected to have more than 60 participating countries. TIMSS, together with PIRLS, comprises the core of IEA's regular cycle of studies. PIRLS (Progress in International Reading Literacy Study) has been assessing reading comprehension at the fourth grade since 2001 on a regular 5-year cycle. Forty countries participated in PIRLS 2006 and PIRLS 2011 is underway. In 2011, TIMSS and PIRLS are being conducted together, providing an unprecedented opportunity to assess mathematics, science, and reading at the fourth grade for the same students in an international context.

Headed by Ina V.S. Mullis and Michael O. Martin, the TIMSS & PIRLS International Study Center is located in the Lynch School of Education. In carrying out the projects, the study center works closely with the IEA Secretariat in Amsterdam, the IEA Data Processing and Research Center in Hamburg, Statistics Canada in Ottawa, and Educational Testing Service in Princeton, New Jersey. For TIMSS Advanced 2008, as in 1995, Bob Garden from New Zealand is the Advanced Mathematics Coordinator and Svein Lie from Norway is the Physics Coordinator. To work with the international team and coordinate within-country activities, each participating country designated one or two individuals to be the TIMSS National Research Coordinator or Coordinators, known as NRCs. TIMSS expends enormous energy to ensure the reliability, validity, and comparability of the data through careful planning and documentation, cooperation among participating countries, standardized procedures, and rigorous attention to quality control throughout. The data are collected according to rigorous scientific standards detailed in procedural manuals and implemented through software applications where appropriate, with countries receiving training every step of the way.

Countries Participating in TIMSS Advanced 2008

Ten countries, with widely divergent socioeconomic characteristics and from different cultural and geographic parts of the world, took part in TIMSS Advanced 2008. They were Armenia, the Islamic Republic of Iran, Italy, Lebanon, the Netherlands, Norway, the Philippines, the Russian Federation, Slovenia, and Sweden. All 10 countries participated in the advanced mathematics assessment and all except the Philippines participated in the physics assessment. In Exhibit 1 the participating countries are shown in two columns, with the five countries that participated in TIMSS Advanced in both 1995 and 2008 shown in green. Four of the five countries have trend data for the advanced mathematics assessment, including Italy, the Russian Federation, Slovenia, and Sweden. A slightly different set of four countries have trend data for the physics assessment, including Norway, the Russian Federation, Slovenia, and Sweden. The decision to participate in any IEA study is coordinated through the IEA Secretariat in Amsterdam and made by each member country according to its own data needs and resources.

Exhibit 1 **Countries Participating in TIMSS Advanced 1995 and 2008**

TIMSSAdvanced2008

SOURCE: IEA TIMSS Advanced 2008 ©

Armenia	Norway
Islamic Rep. of Iran	Philippines
Italy	Russian Federation
Lebanon	Slovenia
Netherlands	Sweden

■ Also participated in 1995

Exhibit 2 presents selected information about the demographic and economic characteristics of the TIMSS Advanced 2008 countries, since such factors are known to influence education policies and decision making. The TIMSS Advanced 2008 countries vary widely in population size and geographic area, as well as in population density. The Russian Federation is by far the largest country in population size and geographic area (142 million people and over 16 million square kilometers) with Armenia, Lebanon, and Slovenia being the smallest (2–4 million people and 10–28 thousand square kilometers). The Netherlands has the highest population density and the Russian Federation the lowest (484 compared to 9 people per square kilometer). The countries also vary widely on indicators of health, such as life expectancy and infant mortality rate. Five countries (Italy, the Netherlands, Norway, Slovenia, and Sweden) had relatively longer life expectancies of 78 years or more and relatively low infant mortality rates (3 or 4 per 1000 live births). The remaining countries reported life expectancies of 68 to 72 years, and infant mortality rates between 13 and 29 out of every 1000 births.

The economic indicators in Exhibit 2, such as the data for gross national income per capita, reveal great disparities in the economic resources available, and also that different policies exist concerning the percent of the gross domestic product (GDP) devoted to education. Economically, the participants ranged from Italy, the Netherlands, Norway, and Sweden (all members of the OECD), with relatively high gross national incomes per capita (in US dollars adjusted for purchasing power parity), to Armenia, Iran, Lebanon, the Philippines, and the Russian Federation with relatively low gross national incomes per capita. In seven of the participating countries, over 90 percent of the relevant age cohort attended primary school. Armenia and Lebanon had somewhat lower rates, and these data were not available for the

Exhibit 2 **Selected Characteristics of the TIMSS Advanced 2008 Countries**

TIMSSAdvanced2008

Country	Population Size (Millions)[1]	Area of Country (1000s of km^2)[2]	Population Density (People/km^2)[3]	Urban Population (%)[4]	Life Expectancy at Birth (Years)[5]	Infant Mortality Rate (per 1,000 Live Births)[6]
Armenia	3	28.2	107	64	72	22
Iran, Islamic Rep. of	71	1628.6	44	68	71	29
Italy	59	294.1	202	68	81	3
Lebanon	4	10.2	400	87	72	26
Netherlands	16	33.9	484	81	80	4
Norway	5	304.3	15	77	80	3
Philippines	88	298.2	295	64	72	23
Russian Federation	142	16381.4	9	73	68	13
Slovenia	2	20.1	100	49	78	3
Sweden	9	410.3	22	84	81	3

Country	Gross National Income per Capita (US $)[7]	GNI per Capita (Purchasing Power Parity)[8]	Public Expenditure on Education (% of GDP)[9]	Net Enrollment Ratio in Education (% of Relevant Group)[10]	
				Primary	Secondary
Armenia	2630	5870	2.7	85	86
Iran, Islamic Rep. of	3540	10840	5.5	94	77
Italy	33490	30190	4.4	99	94
Lebanon	5800	10040	2.7	83	73
Netherlands	45650	39470	5.2	98	88
Norway	77370	53650	7.0	98	96
Philippines	1620	3710	2.5	91	60
Russian Federation	7530	14330	3.1	–	–
Slovenia	21510	26230	5.8	95	90
Sweden	47870	37490	7.1	95	99

All data taken from the *2009 World Development Indicators* (World Bank, 2009) .

1 Includes all residents regardless of legal status or citizenship except refugees not permanently settled in the country of asylum as they are generally considered to be part of their country of origin (pp. 40–43).

2 Area is the total surface area in square kilometers, excluding the area under inland water bodies and national claims to the continental shelf and exclusive economic zones (pp. 134–137).

3 Mid-year population is divided by land area in square kilometers (pp. 14–17).

4 Urban population is the mid-year population of areas defined as urban in each country and reported to the United Nations. It is measured here as the percentage of the total population (pp. 174–177).

5 Number of years a newborn infant would live if prevailing patterns of mortality at its birth were to stay the same throughout its life (pp. 122–125).

6 Infant mortality rate is the number of deaths of infants under 1 year of age, per 1,000 live births in the same year (122–125).

7 GNI per capita in U.S. dollars is converted using the World Bank Atlas method (pp. 14–17).

8 An international dollar has the same purchasing power over GNI as a U.S. dollar in the United States (pp. 14–17).

9 Current and capital public expenditure on primary, secondary, and tertiary education expressed as a percentage of GDP (pp. 80–83)

10 Ratio of the children of official school age who are enrolled in school to the population of the corresponding official school age, based on the International Standard Classification of Education 1997 (pp. 84–87).

A dash (–) indicates comparable data are not available.

Russian Federation. School enrollment rates at the secondary school level were similar to those in primary school in Armenia, Norway, and Sweden. The levels of students enrolled in secondary school were lower in the other countries, with the Philippines having the lowest enrollment rate, 60 percent.

Description of the TIMSS Advanced 2008 Assessment

The publication entitled *TIMSS Advanced 2008 Assessment Frameworks*[2] contains frameworks for the advanced mathematics and physics assessments. Each assessment was organized around two dimensions, a content dimension specifying the subject matter domains to be assessed within advanced mathematics or physics, respectively, and a cognitive dimension specifying the thinking processes or domains to be assessed. The content domains for advanced mathematics are algebra, calculus, and geometry; and for physics they are mechanics, electricity and magnetism, heat and temperature, and atomic and nuclear physics. The cognitive domains are the same for both assessments: knowing, applying, and reasoning. Each cognitive domain is described according to the sets of processing behaviors expected of students as they engage with the mathematics or physics content. The emphasis across the cognitive domains is such that 65 to 70 percent of the assessments measure the applying or reasoning domains.

Developing the tests was a cooperative undertaking involving representatives from the participating countries throughout the process. Participating countries field-tested the items with representative samples of students. The Advanced Mathematics and Physics Coordinators provided guidance throughout the development process, and the National Research Coordinators had several opportunities to review the items and scoring criteria to ensure

2 Garden, R.A., Lie, S., Robitaille, D.F., Angell, C., Martin, M.O., Mullis, I.V.S., Foy, P., & Arora, A. (2006). *TIMSS Advanced 2008 assessment frameworks*. Chestnut Hill, MA: TIMSS & PIRLS International Study Center, Boston College.

the items were measuring objectives in the frameworks, and were appropriate for students in their countries. The advanced mathematics test included 72 items and 82 score points and the physics test included 70 items and 82 score points.[3] Each of the tests was comprised of approximately one third multiple-choice items and two thirds constructed-response items. Chapters 3 and 9, respectively, contain more information about the advanced mathematics and physics tests, including example items. Appendix A contains further information about the numbers of items by type in each domain. Although the assessments were developed collaboratively to represent agreed-upon frameworks, Appendix B contains information about the degree to which the TIMSS Advanced 2008 assessments matched the curricula in the participating countries. In general, the assessment items covered material included in the countries' curricula, and any differences in coverage had little effect on relative performance.

TIMSS Advanced 2008 was conducted in the language of instruction in each country, involving a substantial effort by National Research Coordinators in translating all of the assessment instruments. The translations underwent a complex verification procedure coordinated by the IEA Secretariat, while the test booklet layouts were verified by the TIMSS & PIRLS International Study Center. All student sampling activities for TIMSS Advanced 2008 were monitored by Statistics Canada and conducted with careful attention to quality and comparability. The sampling was designed to ensure that the data provided accurate and economical estimates of the student populations. For the sake of comparability across countries and across assessments, testing for TIMSS Advanced 2008 was generally conducted at the end of the school year (during February through May of 2008 with most countries testing in April). Adherence to the test administration procedures was monitored through the use of international quality

3 One mathematics item and two physics items were deleted due to the analysis results.

control observers arranged by the IEA Secretariat, and also through within-country quality control procedures. The TIMSS & PIRLS International Study Center conducted several training sessions to ensure that the constructed-response scoring was done correctly, and scoring reliability data were collected from each country.

Subsequent to the data collection, the IEA Data Processing and Research Center checked each country's data files for internal consistency and accuracy, and interacted with countries to resolve data issues. The TIMSS & PIRLS International Study Center reviewed achievement item statistics for every country and consulted with Educational Testing Service on the methods and results of the scaling process. The primary approach to reporting the TIMSS Advanced 2008 achievement data was based on item response theory (IRT) scaling methods. More information about the TIMSS Advanced 2008 procedures for sampling, scaling, and data analysis can be found in Appendix A. Details are provided in the *TIMSS Advanced 2008 Technical Report*[4].

All of those involved in the complex task of implementing TIMSS Advanced 2008 met their responsibilities with great dedication, competence, and energy, and are to be commended for their commitment to the project and the high quality of their work. Appendix D lists the names of many of those responsible for the management, coordination, and conduct of TIMSS 2008, including the National Research Coordinators from each participating country.

4 Arora, A., Foy, P., Martin, M.O., & Mullis, I.V.S. (Eds.). (2009). *TIMSS Advanced 2008 technical report*. Chestnut Hill, MA: TIMSS & PIRLS International Study Center, Boston College.