Introduction

SCIENCE

The fact that skills in mathematics and science are so critical to economic progress in a technologically-based society has led countries to seek information about what their school-age populations know and can do in mathematics and science. There is interest in what concepts students understand, how well they can apply their knowledge to problem-solving situations, and whether they can communicate their understandings. Even more vital, countries desire to further their knowledge about what can be done to improve students' understanding of mathematical and scientific concepts, their ability to solve problems, and their attitudes towards learning.

The Third International Mathematics and Science Study (TIMSS) provided countries with a vehicle for investigating these issues while expanding their perspectives of what is possible beyond the confines of their national borders. It is the most ambitious and complex comparative education study in a series of such undertakings conducted during the past 37 years by the International Association for the Evaluation of Educational Achievement (IEA).[1] The main purpose of TIMSS was to focus on educational policies, practices, and outcomes in order to enhance mathematics and science learning within and across systems of education.

With its wealth of information covering more than half a million students at five grade levels in 15,000 schools and more than 40 countries around the world, TIMSS offers an unprecedented opportunity to examine similarities and differences in how mathematics and science education works and how well it works. The study used innovative testing approaches and collected extensive information about the contexts within which students learn mathematics and science.

The present report focuses on the science achievement of primary school students in 26 countries. Participants were to test students in the two grades with the largest proportion of 9-year-olds – the third and fourth grades in most countries. Special emphasis is placed on the fourth-grade results, including selected information about students' background and about classroom practices in teaching science.

The countries that participated in TIMSS tested students in both mathematics and science. A companion report, *Mathematics Achievement in the Primary School Years: IEA's Third International Mathematics and Science Study (TIMSS)*,[2] presents corresponding results about students' mathematics achievement in the lower grades.

[1] The previous IEA mathematics studies were conducted in 1964 and 1980-82, and the science studies in 1970-71 and 1983-84. For information about TIMSS procedures, see Appendix A.

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

Forty-one countries, including those in this report, also tested the mathematics and science achievement of students in the two grades with the largest proportion of 13-year-olds (seventh and eighth grades in most countries). The initial achievement results for the seventh- and eighth-grade students already have been published in two companion volumes:[3]

- *Mathematics Achievement in the Middle School Years: IEA's Third International Mathematics and Science Study*
- *Science Achievement in the Middle School Years: IEA's Third International Mathematics and Science Study*

Approximately 25 of the TIMSS participants also assessed the mathematics and science literacy of students in their final year of secondary education. Additionally, separate samples of students who had taken the relevant coursework were assessed in advanced mathematics and physics. In yet another effort, subsets of students, except the final-year students, also had the opportunity to participate in a "hands-on" performance assessment where they designed experiments and tested hypotheses. The achievement results for the final-year students and for the TIMSS performance assessment will be presented in forthcoming reports.

Together with the achievement tests, TIMSS administered a broad array of background questionnaires. The data collected from students, teachers, and school principals, as well as the system-level information collected from the participating countries, provide an abundance of information for further study and research. TIMSS data make it possible to examine differences in current levels of performance in relation to a wide variety of variables associated with the classroom, school, and national contexts within which education takes place.

Which Countries Participated?

TIMSS was very much a collaborative process among countries. Table 1 shows the countries participating in TIMSS testing at the primary grades. Each participant designated a national center to conduct the activities of the study and a National Research Coordinator (NRC) to assume responsibility for the successful completion of these tasks.[4] For the sake of comparability, all testing was conducted towards the end of the school year. The four countries on a Southern Hemisphere school schedule (Australia, Korea, New Zealand, and Singapore) tested in September through November of 1994, which was the end of their school year. The remaining countries tested the mathematics and science achievement of their students towards the end of the 1994-95 school year, most often in May and June of 1995. Because Italy and Indonesia were

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

[4] Appendix D lists the National Research Coordinators as well as the members of the TIMSS advisory committees.

Table 1

TIMSS Countries Testing in the Primary Grades[1]

- Australia
- Austria
- Canada
- Cyprus
- Czech Republic
- England
- Greece
- Hong Kong
- Hungary
- Iceland
- Indonesia
- Iran, Islamic Republic
- Ireland
- Israel
- Italy
- Japan
- Korea
- Kuwait
- Latvia
- Mexico
- Netherlands
- New Zealand
- Norway
- Portugal
- Scotland
- Singapore
- Slovenia
- Thailand
- United States

[1] Indonesia and Italy were unable to complete the steps necessary for their data to appear in this report.
Please see Appendix A, Figure A.1, for countries participating in other components of the TIMSS achievement testing.
Mexico participated in the testing portion of TIMSS, but chose not to release its results at grades 3 and 4 in the international report.

unable to complete the steps necessary for their inclusion in this report, the tables throughout the report do not include data for these countries. Results also are not presented for Mexico, which chose not to release its third- and fourth-grade results in the international reports.

Table 2 shows information about the lower and upper grades tested in each country, including the country names for those two grades and the years of formal schooling students in those grades had completed when they were tested for TIMSS. Table 2 reveals that for most, but not all, countries, the two grades tested represented the third and fourth years of formal schooling. Thus, solely for convenience, the report often refers to the upper grade tested as the fourth grade and the lower grade tested as the third grade. Two countries, Israel and Kuwait, tested only at the upper grade.

Having valid and efficient samples in each country is crucial to the quality and success of any international comparative study. The accuracy of the survey results depends on the quality of the sampling information available, and particularly on the quality of the samples. TIMSS developed procedures and guidelines to ensure that the national samples were of the highest quality possible. Standards for coverage of the target population, participation rates, and the age of students were established, as were clearly documented procedures on how to obtain the national samples. For the most part, the national samples were drawn in accordance with the TIMSS standards, and achievement results can be compared with confidence. However, despite efforts to meet the TIMSS specifications, some countries did not do so. These countries are specially annotated and/or shown in separate sections of the tables in this report.[5]

[5] The TIMSS sampling requirements and the outcomes of the sampling procedures are described in Appendix A.

Table 2

Information About the Grades Tested

Country	Lower Grade		Upper Grade	
	Country's Name for Lower Grade	Years of Formal Schooling Including Lower Grade[1]	Country's Name for Upper Grade	Years of Formal Schooling Including Upper Grade[1]
[2] Australia	3 or 4	3 or 4	4 or 5	4 or 5
Austria	3	3	4	4
Canada	3	3	4	4
Cyprus	3	3	4	4
Czech Republic	3	3	4	4
England	Year 4	4	Year 5	5
Greece	3	3	4	4
Hong Kong	Primary 3	3	Primary 4	4
Hungary	3	3	4	4
Iceland	3	3	4	4
Iran, Islamic Rep.	3	3	4	4
Ireland	3rd Class	3	4th Class	4
Israel	–	–	4	4
[3] Japan	3rd Grade	3	4th Grade	4
Korea	3rd Grade	3	4th Grade	4
Kuwait	–	–	5	5
Latvia	3	3	4	4
[4] Netherlands	5	3	6	4
[5] New Zealand	Standard 2	3.5–4.5	Standard 3	4.5–5.5
Norway	2	2	3	3
Portugal	3	3	4	4
Scotland	Year 4	4	Year 5	5
Singapore	Primary 3	3	Primary 4	4
Slovenia	3	3	4	4
Thailand	Primary 3	3	Primary 4	4
United States	3	3	4	4

[1] Years of schooling based on the number of years children in the grade level have been in formal schooling, beginning with primary education (International Standard Classification of Education Level 1). Does not include preprimary education.

[2] Australia: Each state/territory has its own policy regarding age of entry to primary school. In 4 of the 8 states/territories students were sampled from grades 3 and 4; in the other four states/territories students were sampled from grades 4 and 5.

[3] Japan: 3rd Grade Elementary and 4th Grade Elementary.

[4] In the Netherlands kindergarten is integrated with primary education. Grade-counting starts at age 4 (formerly kindergarten 1). Formal schooling in reading, writing, and arithmetic starts in grade 3, age 6.

[5] New Zealand: The majority of students begin primary school on or near their 5th birthday so the "years of formal schooling" vary.

SOURCE: IEA Third International Mathematics and Science Study (TIMSS), 1994-95. Information provided by TIMSS National Research Coordinators.

What Was the Nature of the Science Test?

Together with the quality of the samples, the quality of the test also receives considerable scrutiny in any comparative study. All participants wish to ensure that the achievement items are appropriate for their students and reflect their current curriculum. Developing the TIMSS tests was a cooperative venture involving all of the NRCs during the entire process. Through a series of efforts, countries submitted items that were reviewed by science subject-matter specialists, and additional items were written to ensure that the desired science topics were covered adequately. Items were piloted, the results reviewed, and new items were written and piloted. The resulting TIMSS science test contained 97 items representing a range of science topics and skills.

The TIMSS curriculum frameworks described the content dimensions for the TIMSS tests as well as performance expectations (behaviors that might be expected of students in school science).[6] Four content areas are covered in the science test taken by third- and fourth-grade students. These areas and the percentage of the test items devoted to each are earth science (18%), life science (42%), physical science (31%), and environmental issues and the nature of science (9%). The performance expectations include understanding simple information (45%); understanding complex information (31%); theorizing, analyzing, and solving problems (14%); using tools, routine procedures, and science processes (6%); and investigating the natural world (3%).

About one-fourth of the questions were in the free-response format, requiring students to generate and write their answers. These questions, some of which required extended responses, were allotted approximately one-third of the testing time. Responses to the free-response questions were evaluated to capture diagnostic information, and some were scored using procedures that permitted partial credit.[7] Chapter 3 of this report contains 20 example items illustrating the range of science concepts and processes addressed by the TIMSS test.

The TIMSS tests were prepared in English and translated into the additional necessary languages using explicit guidelines and procedures. A series of verification checks were conducted to ensure the comparability of the translations.[8]

The tests were given so that no one student took all of the items, which would have required about four hours for both mathematics and science. Instead, the tests were assembled in eight booklets, containing about one hour of material. Each student took only one booklet,[9] and the items were rotated through the booklets so that each one was answered by a representative sample of students.

[6] Robitaille, D.F., McKnight, C.C., Schmidt, W.H., Britton, E.D., Raizen, S.A., and Nicol, C. (1993). *TIMSS Monograph No. 1: Curriculum Frameworks for Mathematics and Science*. Vancouver, B.C.: Pacific Educational Press.

[7] TIMSS scoring reliability studies within and across countries indicate that the percent of exact agreement for correctness scores averaged over 85%. For more details, see Appendix A.

[8] See Appendix A for more information about the translation procedures.

[9] Primary students were given a break during the testing sessions. Four clusters of items (37 minutes total) were administered prior to the break and three clusters (27 minutes total) after the break.

TIMSS conducted a Test-Curriculum Matching Analysis whereby countries examined the TIMSS test to identify items measuring topics not addressed in their curricula. The analysis showed that omitting such items for each country had little effect on the overall pattern of achievement results across all countries.[10]

How Do Country Characteristics Differ?

International studies of student achievement provide valuable comparative information about student performance and instructional practices. Along with the benefits of international studies, though, are challenges associated with comparing achievement across countries, cultures, and languages. In TIMSS, extensive efforts were made to attend to these issues through careful planning and documentation, cooperation among the participating countries, standardized procedures, and rigorous attention to quality control throughout.[11]

Beyond the integrity of the study procedures, the results of comparative studies such as TIMSS also need to be considered in light of the larger contexts in which students are educated and the kinds of system-wide factors that might influence students' opportunity to learn. A number of these factors are more fully described in *National Contexts for Mathematics and Science Education: An Encyclopedia of the Education Systems Participating in TIMSS*;[12] however, some selected demographic characteristics of the TIMSS countries are presented in Table 3. Table 4 contains information about public expenditure on education. The information in these two tables show that some of the TIMSS countries are densely populated and others are more rural, some are large and some small, and some expend considerably more resources on education than others. Although these factors do not necessarily determine high or low performance in science, they do provide a context for considering the difficulty of the educational task from country to country.

Describing students' educational opportunities also includes understanding the knowledge and skills that students are supposed to master. To help complete the picture of educational practices in the TIMSS countries, science and curriculum specialists within each country provided detailed categorizations of their curriculum guides, textbooks, and curricular materials. The initial results from this effort can

[10] Results of the Test-Curriculum Matching Analysis are presented in Appendix B.

[11] Appendix A contains an overview of the procedures used and cites a number of references providing details about TIMSS methodology.

[12] Robitaille D.F. (Ed.). (1997). *National Contexts for Mathematics and Science Education: An Encyclopedia of the Education Systems Participating in TIMSS.* Vancouver, B.C.: Pacific Educational Press.

Table 3

Selected Demographic Characteristics of TIMSS Countries

Country	Population Size (1,000) [1]	Area of Country (1000 Square Kilometers) [2]	Density (Population per Square Kilometer) [3]	Percentage of Population Living in Urban Areas	Life Expectancy [4]	Percent in Secondary School [5]
Australia	17843	7713	2.29	84.8	77	84
Austria	8028	84	95.28	55.5	77	107
Canada	29248	9976	2.90	76.7	78	88
Cyprus	726	9	77.62	53.6	77	95
Czech Republic	10333	79	130.99	65.3	73	86
[6] England	48533	130	373.33	–	77	–
Greece	10426	132	78.63	64.7	78	99
[7] Hong Kong	6061	1	5691.35	94.8	78	98
Hungary	10261	93	110.03	64.2	70	81
Iceland	266	103	2.56	91.4	79	103
Iran	62550	1648	36.98	58.5	68	66
Ireland	3571	70	50.70	57.4	76	105
Israel	5383	21	252.14	90.5	77	87
Japan	124961	378	329.63	77.5	79	96
Korea	44453	99	444.92	79.8	71	93
Kuwait	1620	18	80.42	96.8	76	60
Latvia	2547	65	40.09	72.6	68	87
Netherlands	15381	37	409.30	88.9	78	93
New Zealand	3493	271	12.78	85.8	76	104
Norway	4337	324	13.31	73.0	78	116
Portugal	9902	92	106.95	35.2	75	81
[8] Scotland	5132	79	65.15	–	75	–
Singapore	2930	1	4635.48	100.0	75	84
Slovenia	1989	20	97.14	62.7	74	85
Thailand	58024	513	111.76	31.9	69	37
United States	260650	9809	27.56	76.0	77	97

[1] Estimates for 1994 based, in most cases, on a de facto definition. Refugees not permanently settled in the country of asylum are generally considered to be part of their country of origin.
[2] Area is the total surface area in square kilometers, comprising all land area and inland waters.
[3] Density is population per square kilometer of total surface area.
[4] Number of years a newborn infant would live if prevailing patterns of mortality at its birth were to stay the same throughout its life.
[5] Gross enrollment of all ages at the secondary level as a percentage of school-age children as defined by each country. This may be reported in excess of 100% if some pupils are younger or older than the country's standard range of secondary school age.
[6] Annual Abstract of Statistics, Office of National Statistics.
[7] Number for Secondary Enrollment is from Education Department (1995) Education Indicators for the Hong Kong Education System (unpublished document).
[8] Registrar General for Scotland Annual Report 1995 and Scottish Abstract of Statistics 1993.
(–) A dash indicates the data were unavailable.
SOURCE: The World Bank, Social Indicators of Development, 1996.

Table 4

Public Expenditure on Education at Primary and Secondary Levels[1] in TIMSS Countries

Country	Gross National Product per Capita (US Dollars)[2]	Gross National Product per Capita (Intl. Dollars)[3]	Public Expenditure on Education (Levels 1 & 2) as % of Gross National Product[4]	Public Expenditure on Education (Intl. Dollars per Capita)[5]
Australia	17980	19000	3.69	701
Austria	24950	20230	4.24	858
Canada	19570	21230	4.62	981
[6] Cyprus	10380	–	3.60	–
Czech Republic	3210	7910	3.75	297
[7] England	18410	18170	3.57	649
Greece	7710	11400	2.27	259
[8] Hong Kong	21650	23080	1.34	309
Hungary	3840	6310	4.31	272
Iceland	24590	18900	4.77	902
Iran	–	4650	3.93	183
Ireland	13630	14550	4.21	613
Israel	14410	15690	3.72	584
Japan	34360	21350	2.82	602
Korea	8220	10540	3.43	362
Kuwait	19040	24500	3.46	848
Latvia	2290	5170	2.85	147
Netherlands	21970	18080	3.30	597
New Zealand	13190	16780	3.15	529
Norway	26480	21120	5.26	1111
Portugal	9370	12400	2.98	370
[7] Scotland	18410	18170	3.57	649
Singapore	23360	21430	3.38	724
Slovenia	7140	–	4.20	–
Thailand	2210	6870	3.00	206
United States	25860	25860	4.02	1040

[1] The levels of education are based on the International Standard Classification of Education. The duration of Primary (level 1) and Secondary (level 2) vary depending on the country.
[2] (SOURCE: The World Bank Atlas, 1996). Estimates for 1994 at current market prices in U.S. dollars, calculated by the conversion method used for the World Bank Atlas.
[3] (SOURCE: The World Bank Atlas, 1996). Converted at purchasing power parity (PPP). PPP is defined as number of units of a country's currency required to buy same amounts of goods and services in domestic market as one dollar would buy in the United States.
[4] (SOURCE: UNESCO Statistical Yearbook, 1995). Calculated by multiplying the Public Expenditure on Education as a % of GNP by the percentage of public education expenditure on the first and second levels of education. Figures represent the most recent figures released.
[5] Calculated by multiplying the GNP per Capita (Intl. Dollars) column by Public Expenditure on Education.
[6] GNP per capita figure for Cyprus is for 1993.
[7] The figures for England and Scotland are for the United Kingdom.
[8] Calculated using Education Department (1995) Education Indicators for the Hong Kong Education System (unpublished document).
(–) A dash indicates the data was unavailable.

be found in two reports, entitled *Many Visions, Many Aims: A Cross-National Investigation of Curricular Intentions in School Mathematics* and *Many Visions, Many Aims: A Cross-National Investigation of Curricular Intentions in School Science*.[13]

Depending on the educational system, students' learning goals are commonly set at one of three main levels: the national or regional level, the school level, or the classroom level. Some countries are highly centralized, with the ministry of education (or highest authority in the system) having exclusive responsibility for making the major decisions governing the direction of education. In others, such decisions are made regionally or locally. Each approach has its strengths and weaknesses. Centralized decision-making can add coherence in curriculum coverage, but may constrain a school or teacher's flexibility in tailoring instruction to the different needs of students.

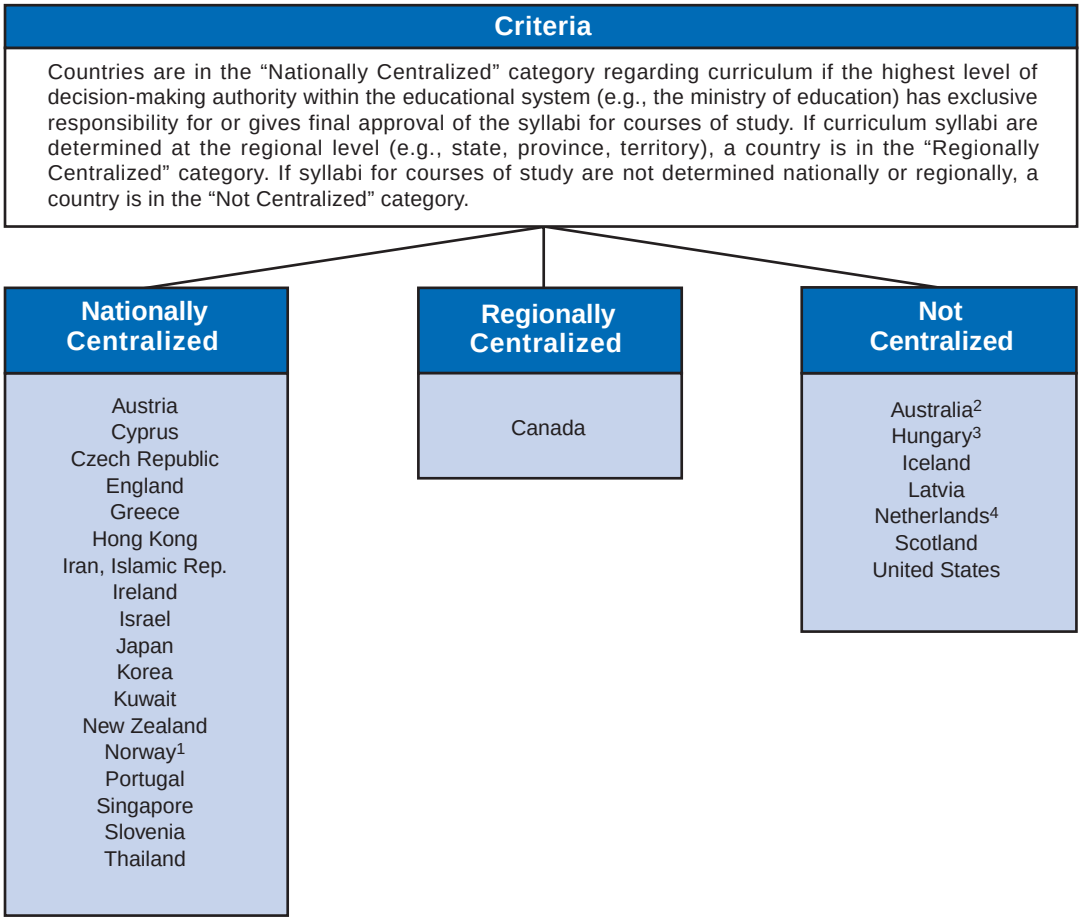
Figures 1, 2, and 3 show the degree of centralization in the TIMSS countries regarding decision-making about curriculum syllabi, textbooks, and examinations. Of the TIMSS participants at the primary school level, 18 reported nationally centralized decision-making about curriculum. Fewer countries reported nationally centralized decision-making about textbooks, although 11 participants were in this category. Five countries reported nationally centralized decision-making about examinations. Regional decision-making about these three aspects of education does not appear to be very common among the TIMSS countries, with only one or two countries reporting this level of decision-making for curriculum syllabi and textbooks, and none reporting it for examinations.

Most countries reported having centralized decision-making for one or two of the areas and "not centralized" decision-making for one or two of the areas. However, only two countries – Hong Kong and Singapore – reported nationally centralized decision-making for all three areas: curriculum syllabi, textbooks, and examinations. Six countries – Australia, Hungary, Iceland, Latvia, Scotland, and the United States – reported that decision-making is not centralized for any of these areas.

[13] Schmidt, W.H., McKnight, C.C., Valverde, G. A., Houang, R.T., and Wiley, D. E. (1997). *Many Visions, Many Aims: A Cross-National Investigation of Curricular Intentions in School Mathematics.* Dordrecht, the Netherlands: Kluwer Academic Publishers. Schmidt, W.H. Raizen, S.A., Britton, E.D., Bianchi, L.J., and Wolfe, R.G. (in press). *Many Visions, Many Aims: A Cross-National Investigation of Curricular Intentions in School Science.* Dordrecht, the Netherlands: Kluwer Academic Publishers.

Figure 1

Centralization of Decision-Making Regarding Curriculum Syllabi



[1] Norway: The National Agency of Education provides goals which schools are required to work towards. Schools have the freedom to implement the goals based on local concerns.

[2] Australia: Students tested in TIMSS were educated under a decentralized system. Reforms beginning in 1994 are introducing regionally centralized (state-determined) curriculum guidelines.

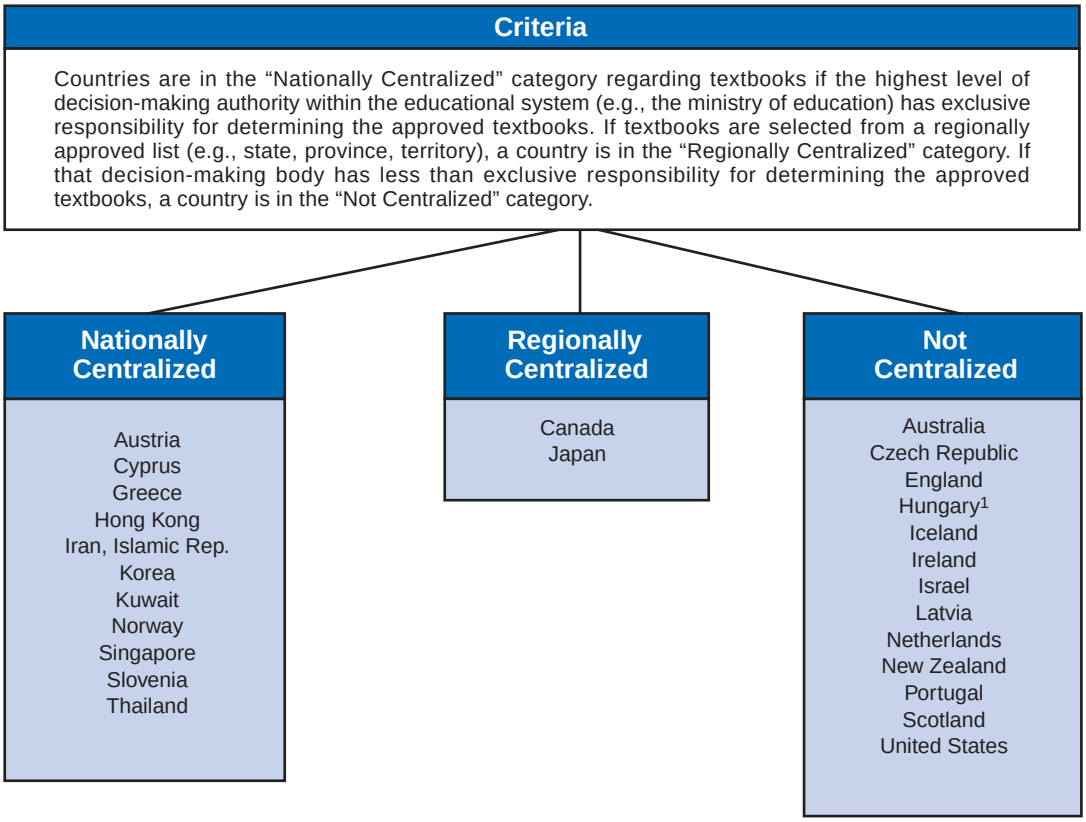
[3] Hungary: Hungary is in the midst of changing from a highly centralized system to one in which local authorities and schools have more autonomy.

[4] Netherlands: The Ministry of Education sets core objectives (for subjects in primary education and in 'basic education' at lower secondary level) and goals/objectives (for subjects in the four student ability tracks in secondary education) which schools are required to work towards. Schools have the freedom, though, to decide how to reach these objectives.

SOURCE: IEA Third International Mathematics and Science Study (TIMSS), 1994-95. Information provided by TIMSS National Research Coordinators.

Figure 2

Centralization of Decision-Making Regarding Textbooks



[1] Hungary: Hungary is in the midst of changing from a highly centralized system to one in which local authorities and schools have more autonomy.

SOURCE: IEA Third International Mathematics and Science Study (TIMSS), 1994-95. Information provided by TIMSS National Research Coordinators.

Figure 3

Centralization of Decision-Making Regarding Examinations

Criteria

Countries are in the "Nationally Centralized" category regarding examinations if the highest level of decision-making authority within the educational system (e.g., the ministry of education) has exclusive responsibility for or gives final approval of the content of examinations. The notes explain during which school years the examinations are administered. If that decision-making body has less than exclusive responsibility for or final approval of the examination content, the country is in the "Not Centralized" category.

Nationally Centralized	Not Centralized
England[1]	Australia[5]
Hong Kong[2]	Austria
Ireland[3]	Canada
New Zealand[4]	Cyprus
Singapore	Czech Republic
	Greece
	Hungary
	Iceland
	Iran, Islamic Rep.
	Israel
	Japan
	Korea
	Kuwait
	Latvia[6]
	Netherlands[7]
	Norway
	Portugal
	Scotland
	Slovenia
	Thailand
	United States

[1] England: Centralized national curriculum assessments taken at Years 2, 6 and 9. Regionally centralized examinations are taken at Years 11 and 13.

[2] Hong Kong: Centralized examination taken at Year 11.

[3] Ireland: Centralized examinations taken at Grades 9 and 12.

[4] New Zealand: Centralized examinations are taken at Years 11, 12 and 13. Centralized national monitoring at Years 4 and 8.

[5] Australia: Not centralized as a country, but low-stakes statewide population assessments are undertaken in most states at one or more of Grades 3, 5, 6,7 and 10. In most states centralized examinations are taken at Grade 12.

[6] Latvia: Centralized examinations taken at Grades 9 and 12.

[7] Netherlands: The majority of schools (71% in 1996) participate in a non-compulsory standardized test which is administered at the end of primary education (Cito eindtoets).School-leaving examinations consisting of a centralized part and a school-bound part are taken in the final grades of the four student ability tracks in secondary education.

SOURCE: IEA Third International Mathematics and Science Study (TIMSS), 1994-95. Information provided by TIMSS National Research Coordinators.