

TRENDS IN INTERNATIONAL MATHEMATICS AND SCIENCE STUDY

TIMSS



TIMSS 2007 Encyclopedia

*A Guide to Mathematics
and Science Education
Around the World*

Volume 2

*M–Z and Benchmarking
Participants*

Edited by

Ina V.S. Mullis

Michael O. Martin

John F. Olson

Debra R. Berger

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Gabrielle M. Stanco



TIMSS & PIRLS
International Study Center
Lynch School of Education, Boston College

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Edited by Ina V.S. Mullis, Michael O. Martin, John F. Olson, Debra R. Berger,
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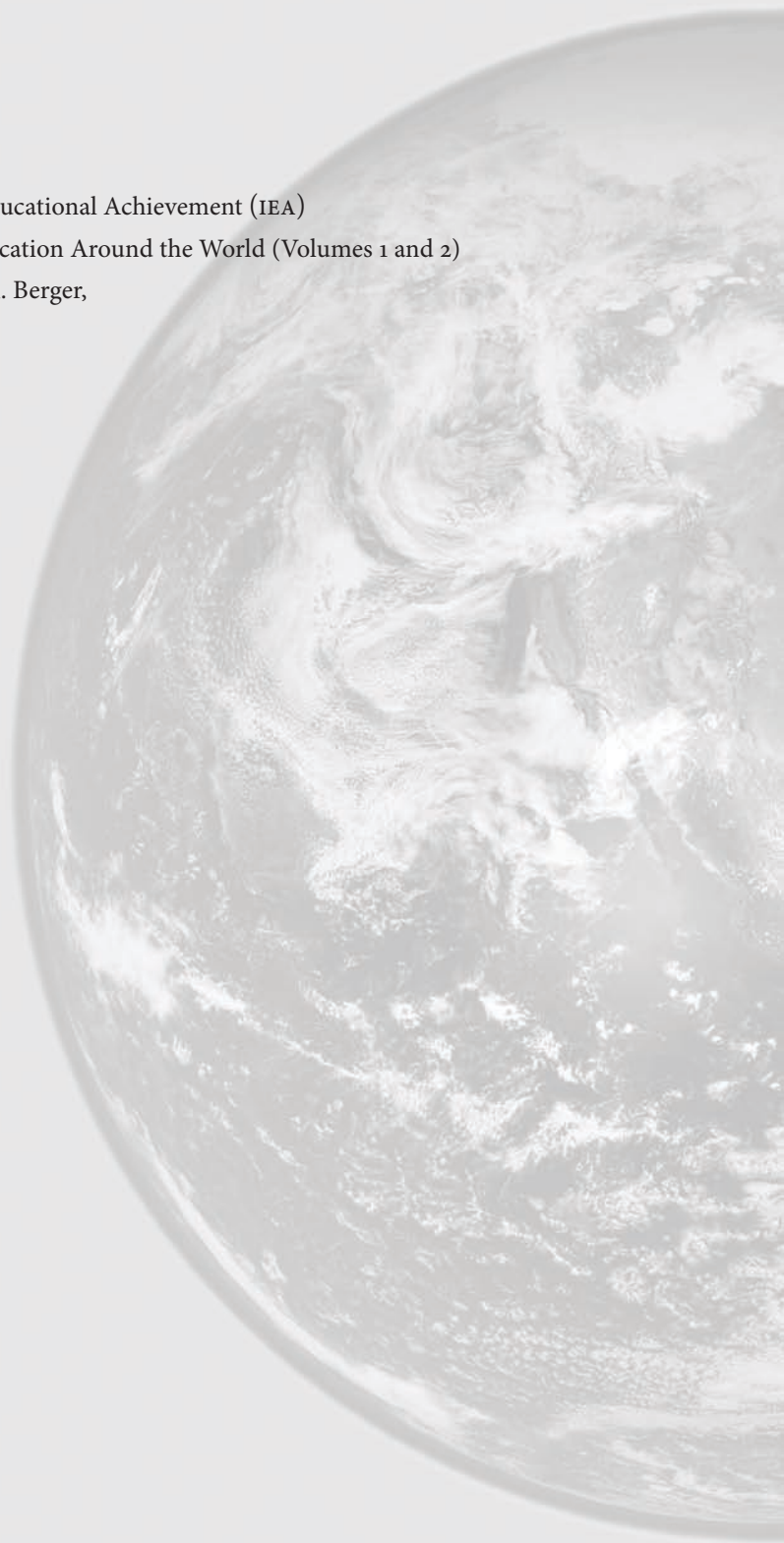
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Malaysia

Hamidah Yusof
Ministry of Education Malaysia

Introduction

Overview of Education System

Providing quality education is one of the main agendas and responsibilities of the Government of Malaysia. The Ministry of Education is committed to providing a comprehensive education to all students. The government funds 95 percent of primary and secondary education and about 60 percent of tertiary or higher education. The Malaysia education system encompasses education from preschool to the university. Preschool, primary, and secondary education is under the jurisdiction of the Ministry of Education, while tertiary education is under the supervision of the Ministry of Higher Education.

Malaysia's goal is to be a regional center of excellence in education. As a result, the education system always has been receptive to innovations and changes. The main purpose of education in Malaysia is to enhance literacy and knowledge and promote intellectual as well as emotional growth.¹ This national aspiration is reflected in the mission statement of the Ministry of Education, "to develop a world class quality education system which will realize the full potential of the individual and fulfill the aspirations of the Malaysian nation."²

Since 1983, the ministry has implemented the Integrated Curriculum for Primary School.³ Primary education is divided into two levels. At level one, from grade 1 to grade 3, the emphasis is on acquiring strong reading, writing, and arithmetic skills. At level two, from grade 4 to grade 6, the mastery of these basic skills is reinforced and emphasized, in order to build a strong foundation in content and basic sciences.

In 1989, the Integrated Curriculum for Secondary School⁴ was implemented. The curriculum covers a wide range of subjects including arts and sciences, as well as vocational and technical subjects. Specifically, the goal of the mathematics curriculum is to develop individuals who are able to think mathematically and who can apply mathematical knowledge effectively and responsibly in solving problems and making decisions.⁵ The goal of the science curriculum is to provide students with knowledge and skills to solve problems and make decisions in everyday life guided by moral values;

pursue further education in science and technology; and develop a concerned, dynamic, and progressive society imbued with a science and technology culture that values nature and works towards the preservation and conservation of the environment.⁶

There are 11 years of free primary and secondary education in Malaysia. Students are admitted to the first year of primary education beginning at age 6. Primary schooling is compulsory for all children between the ages of 6 and 11. Upon completion of secondary education, students can opt to pursue 1 to 2 years of postsecondary education, which is the university entrance preparatory course.

Language and Population

Bahasa Malaysia is the national language and the official language of instruction in all schools. However, English is widely spoken by Malaysians. While the national language is promoted by the government to foster national unity, the people are free to use their mother tongue and other languages in their daily activities.

The school system provides instruction in primary education in the languages of the three main ethnic groups that comprise the Malaysian community: Bahasa Malaysia, Chinese, and Tamil. At the secondary level, Bahasa Malaysia remains the language of instruction. However, since 2003, English has been the language of instruction for mathematics- and science-related subjects. Thus, in 2007, Form 2 (grade 8) students had mathematics and science instruction in Bahasa Malaysia during their 6 years of primary schooling and then started learning both subjects in English for 2 years at the secondary level. Studying both subjects in English, assisted by information and communication technology, provides greater opportunities for students to enhance their knowledge and skills and enables them to access information both in electronic or printed form that is written in English.

Emphasis on Mathematics and Science

Science and technology play a critical role in meeting Malaysia's aspiration to achieve developed nation status. Since mathematics and science are instrumental in developing scientific and technological knowledge, quality education in both subjects from an early age in the education process is important.

Malaysia encourages students to pursue science education at the upper secondary level to meet the demand of the labor force of an industrialized economy. In this respect, the Ministry of Education has formulated a policy aimed at making 60 percent of courses at upper secondary and pre-university levels science and technology related.⁷ Technical education also plays an important role in producing an adequate pool of well-trained and qualified students who excel in mathematics and science as well as in basic engineering subjects. These students are expected to continue their studies in the science- and technology-related courses at the diploma and degree levels.

Overarching Policies Related to Education and the Curriculum for Mathematics and Science

As articulated in the National Education Policy,^{8,9} education in Malaysia is an ongoing effort towards developing the potential of individuals in a holistic and integrated

manner to produce intellectually, spiritually, emotionally, and physically balanced and harmonious individuals.

Science curriculum development in Malaysia also is guided by the National Science Education Philosophy,¹⁰ which states, “science education in Malaysia nurtures a science and technology culture by focusing on the development of individuals who are competitive, dynamic, robust, and resilient and able to master scientific and technological competency. Correspondingly, the science curriculum is designed not only to provide opportunities for students to acquire scientific knowledge and skills; develop thinking skills and strategies; and apply their knowledge and skills in everyday life; but also to instill noble values and the spirit of patriotism through experiential- and inquiry-based learning.

In tandem with the science curriculum, the mathematics curriculum is organized to provide not only opportunities for students to acquire mathematical concepts and skills, but also an understanding of the underlying mathematical thinking and general strategies of problem solving. The curriculum also teaches students how to communicate mathematically and instills positive attitudes towards mathematics, as well as an appreciation of the field of mathematics as an important and powerful tool in everyday life.

The Mathematics Curriculum in Primary and Lower Secondary Grades

Summary of National Curriculum Guides for Mathematics Through Eighth Grade

The curriculum at the primary level, grades 1–4, is organized into four learning areas: numbers, measurement, shape and space, and statistics.¹¹ At the secondary level, grades 5–8, the curriculum is organized into three interrelated learning areas: numbers, shape and space, and relationships.¹²

For each area, topics are listed from the most basic to the most abstract. This enables teachers to have a good understanding of the development and scope of each topic, thus giving them the framework to plan lessons according to the ability of their students. Problem-solving and communication skills are incorporated into each topic.

For grades 1–4, the scope of each topic, based on learning areas and grade levels, is as follows.

Numbers. Upon completing the fourth grade, students should be able to perform mathematical operations and solve problems involving whole numbers up to 100,000. Students also should be able to compare, express equivalent fractions, and add and subtract proper fractions with denominators up to 10. Students should be able to write decimals, convert fractions to decimals, perform mathematical operations, and solve problems involving a maximum of two decimal places. Students should be able to write values, perform mathematical operations, and solve problems involving money up to, RM 10,000 (RM, Malaysia Ringgit, is the country’s currency).

Measurement. In this area, students learn about time. By the end of fourth grade, students should understand the 12-hour system, be able to perform mathematical operations, and solve problems involving units of time and the calendar. Students

also should be able to measure length, mass, and volume of liquid in metric units; do conversions involving the respective units; perform mathematical operations; and solve problems involving length, mass, and the volume of liquid.

Shape and space. Students should be able to identify two- and three-dimensional shapes; calculate perimeters, areas, and volumes; and solve problems involving perimeters, areas, and the volumes of squares, rectangles, cubes, and cuboids.

Statistics. Fourth grade students should be able to extract and interpret information from pictographs and bar graphs.

For grades 5–8, the scope of each topic, based on learning areas and grade levels, is as follows.

Numbers. Upon completing the eighth grade, students should be able to perform computations and solve problems involving directed numbers (integers, fractions, and decimals) and use calculators to explore the concepts having to do with squares, square roots, cubes, and the cube roots of numbers.

Shapes and space. Students should be able to solve problems involving the Pythagorean theorem by the end of the eighth grade. Having learned geometrical construction, students also should be able to perform constructions using straight edges and compasses. Students also should be able to use scales, plot coordinates of points, and solve problems involving coordinates and the distance between two points and midpoints on a Cartesian plane. They also should be able to determine the locus of points that satisfy given conditions and the intersection of two loci.

By the end of grade 8, students should be able to identify parts of a circle; draw a circle given the measurements of the different parts of the circle; and solve problems involving circumference, the area of sectors, and the area of circles. In the area of transformations, students should be able to determine the image of an object and solve problems involving translation, reflection, and rotation; use the concept of isometry in constructing patterns; solve problems involving congruence, and determine properties of quadrilaterals using reflections and rotations. In solid geometry, students should be able to identify geometric properties of prisms, pyramids, cylinders, cones, and spheres; construct models of solids given their nets; and solve problems involving surface areas of prisms, pyramids, cylinders, cones, and spheres.

Relationships. Students should be able to perform computations and solve problems involving algebraic terms and expressions. Eighth grade students should be able to write linear equations and solve problems involving linear equations with one unknown. Students should be able to solve problems involving ratios and proportions of two and three quantities. In statistics, students should be able to collect and record data systematically; determine the frequency of data; and represent and interpret data in pictograms, bar charts, and line graphs and solve related problems.

The Science Curriculum in Primary and Lower Secondary Grades

Summary of National Curriculum Guides for Science Through Eighth Grade

The science curriculum^{13,14} has been designed not only to provide opportunities for students to acquire scientific knowledge and skills, develop thinking skills, and apply this knowledge and skills in everyday life but also to instill scientific attitudes and noble values. These scientific attitudes and values should be integrated into every learning activity. Learning activities should be geared towards activating students' critical and creative thinking skills and not confined to routine or rote learning.

Scientific knowledge encompasses interrelated concepts, facts, rules, or principles associated with biological, chemical, and physical processes as well as astronomy and technology.

Skills refer to scientific and thinking skills utilized in science because of the emphasis on inquiry and problem solving. Scientific skills are important in scientific investigations such as conducting experiments and carrying out projects. One of the objectives of the national education system is to enhance the thinking ability of students. This objective can be achieved through a curriculum that emphasizes thoughtful learning. Teaching and learning that emphasize thinking skills serves as a foundation for thoughtful learning.

Scientific attitudes and values are being instilled through science learning experiences. The inculcation of scientific attitudes and noble values during the teaching and learning of science can be done spontaneously or through planned activities.

Standards for groups of grades are described below.

- **Grades 1–4.** Upon completing the fourth grade, students will have studied living things and nonliving things. Students learn about themselves, animals and plants, and the life processes of humans and animals and how living things survive. They also learn about physical quantities—light, heat, sound, energy, magnets, and electricity—and their measurement. Students learn about man-made and natural materials and their properties. At this stage, students also study the solar system and the development of technologies in agriculture, communication, transportation, and construction.
- **Grades 5–8.** Upon completing the eighth grade, students are able to understand how interactions among living things create a balance in nature. Students also study cells, the human body, and the classification of living things. Learning about matter at this stage provides students with the basis for understanding the variety of resources on Earth and their importance in supporting life. Students also learn about the basic principles of force and motion, energy resources, and the importance of conserving energy resources. Learning about the environment provides understanding of the balance of nature, natural cycles, and the effects of unsystematic management of the environment. In the area of technology, students learn about machines, the strength and stability of structures, and the use of technology. Finally, students learn about natural phenomena due to the movement of the Earth and the moon in astronomy.

Instruction for Mathematics and Science in Primary and Lower Secondary Grades

Instructional Time

At the primary level, from grades 1 to 6, seven periods per week are devoted to the teaching and learning of mathematics, with each period being 30 minutes. At the lower secondary level, mathematics teaching and learning happens five periods per week, with each period lasting 40 minutes.

At grades 1 to 3, science is taught for three periods per week, with each period being 30 minutes. At grades 4 to 6, the number of periods per week for science learning increases to five, with each period also being 30 minutes long. Science at the lower secondary level is taught in five periods per week, with each period lasting 40 minutes.

Instructional Materials, Equipment, and Laboratories

Schools are given the autonomy to determine teaching approaches and strategies. The curriculum specifications for both science and mathematics, however, do provide suggested teaching and learning activities to help teachers plan and implement more effective teaching and learning sessions.

Science teaching and learning at the primary level is carried out in science rooms, while proper laboratories are provided in secondary schools, (some schools have mathematics rooms). The ministry provides annual grants to schools based on school enrollment for the purchase of apparatuses, chemicals, teaching aids, and materials needed for mathematics and science. Schools then directly purchase equipment and materials themselves while the ministry regularly supplies any necessities.

Use of Technology

The Ministry of Education believes that the use of technology helps students understand mathematical and scientific concepts and enables them to explore these ideas extensively. Thus, the use of technology in science and mathematics teaching and learning is encouraged. Technological tools such as calculators, computers, educational software, and the Internet facilitate independent or group work and help students absorb abstract ideas in a meaningful and more precise way, be creative, and feel confident.

The ministry continually supplies computers and teaching software to both primary and secondary schools to enhance the teaching and learning of mathematics and science. The secondary schools are supplied with graphing calculators and Geometer's Sketchpad®. At the primary level, the abacus is used as a tool to enhance mathematics teaching and learning.

Teachers and Teacher Education

Education and Training for Fourth and Eighth Grade Mathematics and Science Teachers

Teaching in Malaysia is a dynamic profession, and education plays a pivotal role in nation building. The National Education Philosophy and Teacher Educational Philosophy serve as the blueprints for creating resilient, professional, and technologically competent teachers who meet world-class standards. These philosophies encompass aspects of

training as well as the continuous professional development of teachers. In a continual quest for excellence, the ministry has upgraded its teacher training colleges throughout the country to teacher training institutes in order to enable these institutions to confer teaching degrees. This move is in line with the ministry's efforts to upgrade and improve the teaching profession as a whole and to enhance the professionalism and competence of teachers specifically. As a graduate profession, teacher training in Malaysia will soon become a reality for both primary and secondary teachers.

Under the ministry, the agencies responsible for training teachers are the Teacher Education Division, the Aminuddin Baki Institute, and public universities. The division is comprised of 27 teacher-training institutes and the English Language Teaching Center. These institutions are responsible for both teacher training and professional development programs, including those in mathematics and science. The ministry practices a stringent admission criterion to ensure that only quality candidates enter the profession. Candidates for the training programs are chosen through the Malaysian Teachers Selection Test, individual and group interviews, and a written English test. Additional requirements are imposed on candidates applying for the postgraduate teaching course according to their specialization. As an example, candidates who apply for the mathematics option must obtain a degree in mathematics as well as a distinction in additional mathematics by taking the Malaysia Certificate of Education examination.

The teacher training programs offered are a 1-year postgraduate teaching course, bachelor of education twinning programs (a collaborative arrangement whereby a local college contracts to teach the first and, often, second year of classes of a partner university located abroad), a 5 1/2-year bachelor of education degree course, and an excellent student overseas degree program.

Teacher Professional Development in Mathematics, Science, and Technology

The professional development programs in mathematics and science include the following: a 1-year specialist course for teachers; postgraduate programs for lecturers; 14-week professional development courses; a degree program for nongraduate teachers; degree programs for foreign language teachers; professional upgrading courses for teachers of indigenous schools, teachers of remote schools, and teachers of smart schools; and a Malaysian trainers development program.

The mathematics and science programs provide students with a sound foundation in the understanding and knowledge of the subject matter, pedagogical skills, and moral values, as well as the use of information technology. The goal of these programs is to produce knowledgeable and skillful teachers who are capable of quality teaching and effective delivery of the curriculum. Focus is given to an experiential learning process to enable the teacher to become a facilitator rather than an information provider.

Overall, the national education policy aspires to produce a group of professionals who can meet the current needs of a changing education system facing the great challenges of globalization.

Examinations and Assessments

National or Regional Examinations

The two examination bodies responsible for conducting the national examinations in Malaysia are the Malaysian Examinations Syndicate and the Malaysian Examinations Council. The syndicate is responsible for the Primary School Achievement Test (*Ujian Pencapaian Sekolah Rendah*), the Lower Secondary School Assessment (*Penilaian Menengah Rendah*), and the Malaysian Certificate of Education (*Sijil Pelajaran Malaysia*). The council is responsible for the Higher Certificate of Education (*Sijil Tinggi Pelajaran Malaysia*). It is important to note that the Education Act of 1996¹⁵ explicitly stated that no examination can be conducted in Malaysia without the written consent from the Director of Examinations of Malaysia.

The roles and purposes of examinations in educational contexts, educational and occupational selection, placement, certification, and the promotion of learning, have not changed substantially throughout history. The primary purpose of examinations in Malaysia is to determine student achievement, which indirectly also determines the effectiveness of programs and teaching methods enabling students to realize their potential. Malaysia advocates the idea that examinations can be used as a means to generate excellence in nation building, especially in the aspect of human capital.

There are four major national examinations throughout the 13 years of schooling. At the end of grade 6, students sit for the Primary School Achievement Test. The result of this assessment is used as a reference for entry into certain schools. At grade 9, students sit for the Lower Secondary School Assessment, a combination of centralized and school-based assessments. At this point, results are used as an indicator to channel students into science, arts, and technical streams. Mathematics and science are compulsory subjects in these two examinations. Students' results are reported in result slips, neither pass nor fail performances are recorded in either examination. At grade 11, students sit for the Malaysian Certificate of Education. Mathematics and science are compulsory subjects, whereas additional mathematics, physics, chemistry, and biology subjects are electives. Students are required to pass additional mathematics with at least a credit before they can be accepted for most courses offered in pre-university or university programs. The minimum standard for a pass with credit on the Malaysian Certificate of Education is equivalent to the standard in the United Kingdom, where a grade of C or above on the General Certificate in Secondary Education is considered passing with credit.

With the Malaysian Certificate of Education, students can choose to receive a matriculation diploma, or enter a pre-university or university program. Students also can opt to continue schooling for 2 more years until grade 13 to sit for the Higher Certificate of Education before pursuing further studies.

Other Tests

School-based assessments are designed by the Malaysian Examinations Council to test skills, such as the scientific process and scientific problem solving and values, conducted through the Assessment of Practical Science (*Pentaksiran Kerja Amali Sains*). This is

a formative type of assessment that is planned, administered, scored, evaluated, and reported by the school. This assessment is conducted during teaching and learning for all science subjects. Students' learning experiences can be maximized and modified during the formative assessment and evaluation stage. At the same time, summative assessment monitors students' attainment of expectations. Furthermore, summative assessment is used in decision making about the end product of the process, and it also provides a platform for program improvements in the future. Schools also conduct their own internal assessments. However, marks, grades, and report cards from the assessment by the school are utilized at the school level.

Malaysia advocates assessment for learning or formative assessment as well as assessment of learning. Therefore, efforts in improving educational and instructional performances in all schools through positive assessment and evaluation practices continue to be an important educational agenda in nation building.

Grade Promotion and Retention Policies

Students undergo automatic promotion during the primary and the secondary level of schooling until grade 11. Thus, there is no retention or requirement to repeat the entire academic year should a student fail to meet the minimal requirements.

Suggested Readings

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Malta

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Introduction

Overview of Education System

The Legal Framework of the Maltese National Minimum Curriculum¹ can be found in the 1988 Education Act, as amended by Act XIII of 2006. The Education Act empowers the minister responsible for education to make provisions for the appointment, conditions of employment, and duties and powers of teachers, as well as to determine a national curriculum of studies without prejudice to the specific religious nature of any school. This legal document is supported by a policy document, *Creating the Future Together*² that outlines the National Minimum Curriculum. The educational objectives targeted in this document can be realized through teaching and training that enables students to acquire knowledge, skills, and attitudes related to several areas that benefit human development. The curriculum encourages dialogue between those involved in these different levels of the educational process, thus guaranteeing the continuity of methodology and assessment policies and the elimination of unnecessary repetition of content.

The compulsory educational program for students ages 5–16 is divided into two phases: primary (ages 5 to 10 years), and secondary (ages 11 to 16 years). The organization of secondary schools is based on year groups called “forms”. The first year of secondary education would be form 1, the second year form 2, etc. Kindergarten or preprimary education (2 years, 9 months to 5 years) is not part of compulsory education.

The main goal of the curriculum at the kindergarten level is to enhance the holistic development of students. More specifically, it targets students’ intellectual, socio-emotional, physical, and moral development, as well as the development of a sense of aesthetics and creativity.

Primary education is a two-pronged process. The first phase connects with a 2-year kindergarten period, while the second phase connects with the secondary school years. The national curriculum ensures a smooth transition from one level to another. The primary school program attaches importance to the learning of a repertoire of skills, the strengthening of personal and social education, and the development of enhanced

skills, knowledge, and attitudes linked to the basic subjects. It also aims to fulfill the principle of education for diversity. The curriculum links summative and formative forms of assessment and implements a policy of bilingualism, the teaching of religion, and parent education programs.

At the **secondary** level, the Education Division and the University of Malta Matriculation Secondary Education Certificate Board³ strive to work together to achieve the set goals. These include the strengthening and refinement of the skills developed at the primary level, the strengthening of personal and social education and the implementation of the broad aims within the curriculum content, as well as the implementation of a policy for language teaching. The development of projects revolves around themes that focus, among other areas, on the teaching of religion and the strengthening of emotional development and parent participation.

The present educational challenges include the implementation of a national lifelong learning program, an information technology awareness program for all ages, and the further enhancement of a quality assurance program. The latter already has resulted in a change in the education administration system in order to provide the necessary support and reach the objectives set by the Lisbon Agenda, which includes making education a priority in European Union countries.

Language and Population

The National Minimum Curriculum considers bilingualism as the basis of the education system. This document regards bilingualism as entailing the effective, precise, and confident use of the country's two official languages: Maltese, the national language, and English. Students must attain this goal by the end of their entire schooling experience. Therefore, students are provided with every opportunity to develop their first language, Maltese. The school must ensure that students are familiarizing themselves with the second language, English.

The National Minimum Curriculum encourages teachers at the primary level to use English as the language of instruction when teaching English, mathematics, science, and technology. In difficult situations, code switching or using more than one language can be used as a means of communication. At the secondary level, the curriculum requires teachers of Maltese and English to teach in the language of the subject and recommends that teachers of foreign languages teach in that language. Teachers of social studies, history, religion, and personal and social education teach these subjects in Maltese. All other subjects are to be taught in English.

The Mathematics Curriculum in Primary and Lower Secondary Grades

Summary of National Curriculum Guides for Mathematics Through Eighth Grade

The curriculum for individual subjects is established by an appointed group of experts in light of the official legal and policy documents related to education.

Mathematics in the early years (preprimary level) is taught through children's everyday experiences, many of which have a mathematical component to them. Besides

number and computation, children are helped to develop the initial skills in problem solving, data handling, measurement, shape, and space. Opportunities are provided to add, subtract, multiply, and divide using situations in daily life. Children are helped to develop their experience and understanding of measuring, applying this to length and area, volume and capacity, weight, time, and money.

Children also are introduced to the practice of measuring anything appropriate with standard units, kilograms, minutes, centimeters, and nonstandard units. As they become more familiar with the measuring process, they are encouraged to estimate before they measure and then compare their findings to the estimate.

The mathematics program for primary school⁴ aims to help students appreciate the value of mathematics, foster a sense of creative interest in mathematics, and develop skills, concepts, understandings, and attitudes that will enable them to confidently cope with the mathematics of everyday life. The goal of the program also is to develop a variety of problem-solving strategies so that students become mathematically literate in a world that is technologically oriented and information rich, and provide them with a foundation to further their studies in mathematics or other subjects. Mathematics is taught for 1 hour every morning in primary school, with teachers helping students appreciate the importance of mathematics in their lives. They achieve this by using a thematic approach.

The achievement goals of the mathematics curriculum in **primary school** are the following.

- **Number and algebra.** The mathematics curriculum provides opportunities for students to develop an understanding of numbers, together with accuracy, efficiency, and confidence in calculating mentally and on paper. It fosters an ability to estimate and make approximations, check the reasonableness of results and measurements, and recognize patterns and relationships in mathematics and the real world. It also promotes the ability to use symbols, notation, and graphs.
- **Measure, shape, and space.** The mathematics curriculum provides opportunities for students to gain knowledge of geometrical relations in two and three dimensions and recognize and appreciate their occurrence in the environment. It also helps to develop spatial awareness and the ability to recognize and make use of the geometrical properties and symmetries of everyday objects. Students gain the ability to use geometrical models as aids to solving practical problems in time and space, develop knowledge and understanding of systems of measurement and their use and interpretation, and obtain confidence and competence in using instruments and measuring devices.
- **Data handling.** The mathematics curriculum provides opportunities for students to recognize appropriate statistical data for collection and develop the skills of collecting, organizing, and analyzing data, as well as interpreting this data in tables, charts, and graphs of various kinds.
- **Problem solving.** The mathematics curriculum provides opportunities for students to develop flexibility and creativity in applying mathematical ideas and

techniques and become effective participants in problem-solving teams. Students also learn to develop the skills of presentation and the critical appraisal of a mathematical argument or calculation, as well as the characteristics of logical and systematic thinking, and apply these in mathematical and other contexts, while developing skills and confidence to use the language of mathematics to express mathematical ideas.

According to the national mathematics curriculum, students are taught each of the following topics or skills by the end of **form 3 (grade 9)**.

- *Number*: whole numbers including place value, factorization, and the four operations; computations, estimations, or approximations involving whole numbers; common fractions including equivalent fractions and ordering fractions; decimals, including place value, ordering, and converting to common fractions; representing decimals and fractions using words, numbers, or models; computations with fractions and decimals; representing, comparing, ordering, and computing with integers; ratios (equivalence and division of a quantity by a given ratio); and conversion of percents to fractions or decimals and vice versa.
- *Algebra*: numeric, algebraic, and geometric patterns or sequences; evaluating expressions for given numeric values; simplifying or comparing algebraic expressions; modeling situations using expressions; evaluating functions or formulas for given values of the variables; and equivalent representations of functions as ordered pairs, tables, graphs, words, or equations.
- *Geometry*: angles, including acute, right, straight, obtuse, and reflex; relationships for angles on a line, vertically opposite angles, angles associated with a transversal cutting parallel lines, and perpendicularity; properties of geometric shapes; triangles, quadrilaterals, and other common polygons; constructing or drawing triangles and rectangles of given dimensions; Pythagorean theorem (not proof) to find the length of a side; measurement, drawing, and estimation of the size of angles, the length of lines, areas, and volumes; measurement formulas for perimeters, circumferences, areas of circles, surface areas, and volumes; Cartesian plane-ordered pairs, equations, intercepts, intersections, and gradient; line and rotational symmetry for two-dimensional shapes; and translation, reflection, and rotation.
- *Data and chance*: reading data from tables, pictographs, bar graphs, pie charts, and line graphs; organizing and displaying data using tables, pictographs, bar graphs, pie charts, and line graphs; characteristics of data sets including mean, median, range, and shape of the distribution (in general terms); interpreting data sets (e.g., drawing conclusions and making estimate values between and beyond given data points; and using the chances of a particular outcome to solve problems.

The Science Curriculum in Primary and Lower Secondary Grades

Summary of National Curriculum Guides for Science Through Eighth Grade

The science program for primary schools is designed to implement the objectives stated in the National Minimum Curriculum. Objective 12 of the National Minimum Curriculum focuses on the need for students to have a “greater awareness of the role of science and technology in everyday life.” The Primary Science Framework aims to lay the foundation of knowledge and understanding and develop the skills and attitudes related to science through first-hand experience. This foundation, mainly based on a weekly half hour lesson, is intended to lead to a deeper progressive understanding of scientific activity, forming a basis for further study in science at secondary level. The National Minimum Curriculum elaborates on the aspects of knowledge, skills, and attitudes in science. While attitudes are constantly kept in mind when organizing scientific activities, strands termed “Acquiring Scientific Knowledge” (strand 1) and “Acquiring Scientific Knowledge” (strand 2) are structured in levels to be achieved at different years.

In the early **primary years (grades 1–3)**, students are expected to be able to use their senses to observe and group objects and events in their immediate environment and identify possible situations for scientific investigation. They use these observations to make predictions or suggest possible solutions and simple investigations and to make simple, nonstandard, and standard measurements in an effective manner. They also carry out investigations in a group, make a simple evaluation by describing whether what happened was expected, and share what they did and what they found out with the whole class.

In the later **primary years (grades 4–6)**, students are expected to be able to compare and classify objects and events in their immediate environment and use these ideas to make testable predictions and discover ways to carry out fair tests. They also learn to select appropriate resources and instruments and use standard measurements with appropriate precision. Students gain experience in how to organize themselves within a group and with members having different responsibilities while working as a team. They record data and analyze it using graphs and information processing technologies to find patterns. The group then draws conclusions that reflect the information collected and evaluates the process and generates ideas while presenting well-reasoned, complete reports to the whole class.

The teaching of geography at the primary level forms part of a teaching program of social studies that encompasses the areas of history, environmental studies, and geography. The geography program aims at making the young students aware of the different aspects that influence Maltese society in a Euro-Mediterranean background as a starting point to a wider and more global perspective. It is expected that by the end of primary education, the majority of students would have attained level 4 of the 8 scale levels in the compulsory program for the teaching of geography as a nonspecialized subject.

Level 1 aims, through oral expression, to instill awareness about the immediate local environment (the classroom, the local town, or village) through the observation of the natural life cycle, including day and night, as well as the different seasons.

At *level 2*, through oral and artistic expression and some basic writing, students become aware of the physical and human elements in their immediate surroundings. At this level, students are encouraged to reason out and express their views about daily life happenings, including the weather.

At *level 3* students become aware of the physical and human elements in Malta, the Mediterranean, and the world. These include physical and environmental features that encourage and support basic geographical research.

At *level 4*, through oral and written expression, as well as through pictures and maps, students are able to give an explanation to a wide spectrum of physical elements pertaining to the Maltese islands, including the explanation of interactive changes resulting from the different cycles. Emphasis is laid on reasons underlying the contrast between the Maltese environment and that of other Mediterranean countries. The collection of geographical data and its presentation forms the basis for a geographical study carried out in the school. Simple map interpretation and the use of photos and technological support are used for the collection of data.

During the first 2 years of **secondary education**, the curriculum envisages that students learn integrated science. The Science Framework adopted in forms 1 and 2 builds on the Primary Science Framework, which is organized into four strands: investigating scientifically, life science, physical science, and earth and space science. Each strand is organized into a number of units. Each unit is made up of student outcome statements and student learning expectations. This framework extends opportunities for students to have a better understanding of themselves and the empirical world around them and to improve on their communications skills. It also enables them to solve problems, think scientifically, and develop those attitudes that are required for good personal and social relationships, while furthering their awareness of the culture which is science. Students have 3 hours per week allotted for the subject.

Beginning in the third year and until the final year of secondary education (forms 3, 4, and 5), physics replaces integrated science as the scientific core subject for students in state schools. Those in nonstate schools can choose one option from among biology, chemistry, or physics as their compulsory scientific core curriculum subject. During the last 3 years of secondary education, students have to choose two subjects to study as core curriculum options. Students choosing the scientific strand can opt for biology and chemistry as their two subjects. Four lessons (each 45 minutes) a week per subject is allocated for core curriculum options.

Maltese students learn geography instead of earth science, which is taught for 45 minutes a week. There are students who choose geography as their core curriculum option for the last 3 years of secondary education. In nonstate schools, students also have the option of choosing environmental science instead of geography. More specifically, the curriculum guides for **geography** through **form 3** include the following.

- *Geography*: Earth's structure and physical features (Earth's crust, mantle, and core); topographic maps; the physical state, movement, composition, and the

relative distribution of water on Earth; the Earth's atmosphere and the relative abundance of its main components; Earth's water cycle (steps and the role of the sun's energy and circulation or renewal of fresh water); processes in the rock cycle and the formation of igneous, metamorphic, and sedimentary rock; geological processes occurring over millions of years (e.g., erosion, mountain building, and plate movement); formation of fossils and fossil fuels; environmental concerns (e.g., pollution, global warming, and acid rain); and an explanation of phenomena on Earth based on position or movement of bodies in the solar system and the universe (e.g., day or night, tides, year, phases of the moon and eclipses, seasons, planets, and constellations).

Students opting for biology at the form 3 level are taught the subject for 3 hours a week. They follow a syllabus that enables them to develop an awareness of the various forms of life, as well as knowledge and understanding of basic anatomical and physiological characteristics of organisms. They develop an awareness of the different interactions between organisms, as well as between the organisms and their environment and a scientific approach to problem solving that incorporates the analysis and interpretation of experimental data. Students acquire a range of communicative and manipulative skills appropriate for biology that enhance a working knowledge of other fields of study (e.g., mathematics, chemistry, physics, and geography), vital for a proper understanding of biological concepts. They also attain a positive educational experience that can serve to motivate students to further their studies in biology. More specifically, the curriculum guides for **biology** through **form 3** include the following.

- *Biology*: classification of organisms on the basis of a variety of physical and behavioral characteristics; cell structures and functions; photosynthesis and respiration (including substances used and produced) as processes of cells and organisms; life cycles of organisms, including humans, plants, birds, and insects; reproduction (sexual and asexual) and heredity (passing on traits and inherited versus acquired or learned characteristics); the role of variation and adaptation in survival or the extension of species in a changing environment; the interaction of living organisms in an ecosystem (energy flow, food chains and food webs, food pyramids, and the effects of change upon the system); the impact of natural hazards on humans, wildlife, and the environment; causes of common infectious diseases, methods of infection or transmission, prevention, and the body's natural resistance and healing capabilities; and preventive medicine methods (diet, hygiene, exercise, and lifestyle).

Students opting for chemistry at the form 3 level are taught the subject for 3 hours a week. The main aim is to develop an appreciation of the environmental and technological contributions and applications of chemistry. Students follow a syllabus that enables them to stimulate and sustain their interest and enjoyment in the learning of chemistry and its role in our everyday lives. The syllabus provides a relevant chemical background for those who intend to terminate their study of chemistry at the secondary level and also lays a sound foundation for those who intend to pursue their studies in chemistry or related

subjects. It enables students to acquire knowledge and understanding of basic chemical principles and patterns and encourages them to apply their chemical knowledge and understanding to familiar and unfamiliar situations. Students improve their abilities to perform experiments through a guided development of relevant practical skills, while learning correct and safe laboratory practice. They develop an investigative competence in relation to problem-solving situations and an ability to communicate their chemical knowledge and findings in appropriate ways. More specifically, the curriculum guides for **chemistry** through **form 3** include the following.

- *Chemistry*: classification and composition of matter (physical and chemical properties, pure substances and mixtures, and separation techniques); the particulate structure of matter (molecules, atoms, protons, neutrons, and electrons); solutions (solvents, solutes, and the effect of temperature on solubility); properties and uses of water (composition, melting or boiling points, and changes in density or volume); the properties and uses of common acids and bases; chemical change (transformation of reactants), evidence of chemical change and the conservation of matter; and common oxidation reactions (combustion and rusting), the need for oxygen, and the relative tendency of familiar substances to undergo these reactions.

Physics at the form 3, 4, and 5 levels is compulsory for all students, and the subject is taught for 3 hours a week. The physics syllabus aims to develop students' understanding of the nature of scientific ideas and activity through the acquisition of a systematic body of scientific knowledge and an appreciation of its power and limitations. The scientific method is presented as a method of inquiry in a way that stimulates curiosity and interest. An investigative teaching approach is followed. Every opportunity is taken to expose the students to the application of physics to technology and environmental issues. Students follow a syllabus that enables them to emphasize the importance of the process of scientific investigation as a means of solving problems in everyday life and also contributes to the students' general education by helping to make sense of the physical environment through scientific inquiry. The study of physics provides the basis for further study of the subject and develops experimental and investigative abilities, as well as the skills necessary to find solutions to scientific problems. Students develop positive attitudes towards physics and science, in general, and the environment and carry out scientific investigation in a practical manner. More specifically, the curriculum guides for **physics** through **form 3** include the following.

- *Physics*: physical states and changes in matter (explanations of properties including volume, shape, density, and compressibility in terms of movement or distance between particles, and conservation of mass during physical changes; processes of melting, freezing, evaporation, and condensation (phase change); melting or boiling points; effects of pressure and purity of substances; energy forms, transformations, and heat and temperature, including heat transfer; temperature changes related to changes in volume and/or pressure and changes

in movement or speed of particles; basic properties or the behavior of light (reflections, refraction, light and color, and simple ray diagrams); properties of sound (transmission through media and ways of describing sound: loudness, pitch, amplitude, frequency, and relative speed); electric circuits (flow of current and types of circuits, including parallel or series) and the relationship between voltage and current; and forces and motion (types of forces and the basic description of motion) and use of distance or time graphs.

Instruction for Mathematics and Science in Primary and Lower Secondary Grades

Use of Technology

Computers are learning tools, which students use to discover and reinforce new ideas. Information and communication technology (ICT) provides primary level students with opportunities to learn from feedback, observe patterns, and see connections; work with dynamic images; explore data; and learn to use a computer.

The use of ICT in the secondary level gives students the potential to make a significant contribution to their learning in mathematics by helping them practice and consolidate number skills, experiment with and make hypotheses, discuss or explain relationships in shape and space, and develop logical thinking and modify assumptions and strategies through immediate feedback. Students make connections within and across the different areas of mathematics; work with realistic sets of data; explore, describe, and explain patterns and relationships in sequences and tables of numbers; and develop skills in mathematical modeling through the exploration, interpretation, and explanation of data. Students are expected to use ICT to answer valid questions appropriate to the subject matter being taught. Students also engage in practical and experimental work in order to appreciate principles that govern random events and look critically at some of the ways in which representations of data can be misleading and conclusions can be uncertain.

In secondary level mathematics courses, students are given the opportunity to use calculators and computer software (e.g., Logo, a dynamic geometry package, and a computer algebra system). They use computers as a source of large samples, a tool for exploring graphical representations and a means for simulating events. They also use computers to generate and transform graphic images and solve problems, formulate questions that can be solved using statistical methods, and undertake purposeful inquiries based on data analysis.

Teachers and Teacher Education

Education and Training for Fourth and Eighth Grade Mathematics and Science Teachers

All school teachers in Malta are subject to the official regulation that “no person may exercise the profession of teacher in a school and receive remuneration thereof without a warrant from the minister.” Paragraph 24 of the Education Act, Chapter 327 of 2006, lays down the conditions for the issue of a permanent warrant.⁵

Teachers who satisfy the requirements are awarded a permanent warrant. However, the minister may grant a temporary warrant valid for a year to any person who, at the discretion of the minister, has the required ability to teach in Malta. The minister also may suspend any warrant granted under the provisions of the Education Act, when the holder is guilty of a breach of the Code of Behavior provided for by regulations under the Education Act.

At present, there are two main channels for obtaining a permanent warrant. The first option is to follow a 4-year Bachelor of Education honors course at the University of Malta or any other recognized university and specialize in either primary or secondary teaching. At the secondary level, Bachelor of Education students specialize in two main subjects in order to be more flexible in their teaching. In both cases, the course covers both the theoretical and practical aspects of pedagogy. Another option in obtaining a permanent teacher's warrant is to receive a first degree from any recognized university and a postgraduate certificate or diploma in education as a teacher at the secondary level or a diploma or certificate in primary education.

Since teaching in Maltese schools is bilingual, teachers must be proficient in both languages at the primary level.⁶ At the secondary level, prospective Bachelor of Education students pass a proficiency test in English prior to enrolling in the course. No teacher may obtain a permanent warrant if he or she does not meet the required standard in both languages. Since the introduction of computer literacy at all levels in all schools, prospective teachers should be in possession of a full certificate of the European Computer Driving License,⁷ the European-wide qualification demonstrating competence in computer skills, as one of the entry qualifications for a Bachelor of Education or a postgraduate certificate or diploma in education.

Teacher Professional Development in Mathematics, Science, and Technology

Each teacher may participate annually in a refresher course that takes place at the end of the scholastic year or prior to the start of the new school year. These courses may be related specifically to subject teaching or may be more generic, relating to general teaching policies, updating teaching strategies, or more generally related to teaching and learning.

Examinations and Assessments

National or Regional Examinations

In state schools, no formal assessment in examination form takes place during the first 3 years of primary education. Formal assessment starts in the fourth year of primary school. The assessment system consists of a school-based test in February and a national test at the end of the scholastic year in June. The aim of these tests or examinations is to monitor the level of student attainment from one level to another rather than penalizing those who have not reached the desired targets.

Since October 2007, a formative assessment instrument, referred to as the Record of Student Achievement, has developed formative assessment from a class- or school-

based system to a national level. This assessment is mandatory for all students from primary education up to the end of compulsory education. At the kindergarten level, a similar instrument, Record of Development and Progress at Kindergarten Level, also has been introduced.

Performance on an 11-plus examination classifies students into two groups, those attending junior lyceums, and for those students who do not qualify for the junior lyceums, those attending secondary schools. Junior lyceums are deemed to be open to more than 55 percent of the yearly cohort in state schools.

In church and independent schools, the system of examination and assessment varies considerably at all levels. However, church schools organize an 11-plus examination known as the Common Entrance Examination for boys since several male schools do not offer primary education. Each year, between 450 and 500 boys are chosen for admission to secondary education in church schools. Girls' church schools offer the whole 5- to 16-year educational program and therefore, this examination does not apply.

At the secondary level, a formative and summative assessment is used in state schools. There are two examinations: the midyear and the annual. At age 16, students sit for their annual examination and are awarded a school-leaving certificate that marks the end of compulsory education. Students also sit for the Secondary Education Certificate Examination administered by the University of Malta. About 82 percent of the cohort sits for this examination. Passing this examination opens opportunities for further education leading either to a 2-year general education course and the Matriculation Certificate that is the entrance requirement for university studies or a vocational course at the Malta College of Arts, Science, and Technology,⁸ where several courses also are available to students in possession of a school-leaving certificate.

Grade Promotion and Retention Policies

The number of students repeating a year is very minimal, since the National Curriculum provides enough space for schools to tackle the educational realities of their students.⁹

Suggested Readings

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Mongolia

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Introduction

Overview of Education System

In Mongolia, the Ministry of Education, Culture, and Science is the agency responsible for the education sector and, specifically, for developing the curriculum and educational standards.

In 1991, the Educational Law of Mongolia prescribed that preschool education be included in the general educational structure. The Mongolian education system, therefore, offers up to 4 years of noncompulsory preschool education, including kindergarten and nursery school. Kindergarten in Mongolia is designed for training and upbringing, with the goal of providing children, ages 3–7, with education and practical skills that are physically and developmentally appropriate.¹

Most children enter primary school at age 7 and remain there for 5 years. This stage is followed by 4 years of lower secondary education. Primary and lower secondary education together are considered basic education and are compulsory. Basic education is followed by 2 years of upper secondary education, a prerequisite for university admission. The current 11-year system, with 9 compulsory years, has been in effect since 2005 and is based on the amendment to the Law on Education and Law on Primary and Secondary Education of May 2002. However, starting in the 2008 school year, children will be allowed to enter primary school at age 6, shifting the structure of the education system to a 12-year system by 2014.²

The technical education and vocational training subsector is comprised of specialized upper secondary schools, as well as postsecondary diploma programs housed in higher education institutions. Higher education and science technology make up two separate subsectors. In addition, there is a nonformal education subsector.

Since the 1990s, Mongolia has reformed its education sector based on the social and individual needs in the new millennium. The reform effort has required a new curriculum at all levels, revision of school textbooks, a change in teaching and learning methods,³ a revision of educational standards (2001–2003) and new content standards

for all subjects in each grade (developed by the Education Institute), and a shift to a 12-year system of schooling.

Furthermore, the ongoing reforms that focus on decentralization in Mongolian education are designed to change the system from a highly specialized and compartmentalized model to a more flexible system with improved efficiency and effectiveness at all levels. Since 1990, there has been a relaxation of state control over curriculum in Mongolia and efforts at diversification based on local community needs. This includes eliminating ideological content and shifting from a teacher-centered to a more student-centered curriculum. Administration of schools at all levels has been decentralized and less reliance is placed on national planning approaches to accommodating students with various types of curricula. The government has introduced measures aimed at cost sharing with parents and students so that education funding can be supplemented by sources other than the central government. The government also has passed legislation allowing the private sector provision of education at all levels.⁴

Language and Population

While there are over 16 recognized clans and ethnic groups in Mongolia, most of the groups speak Mongolian with slight differences in dialects. Therefore, the official language, as well as the instructional language, in most schools is Mongolian. One exception is the Kazakhs, the biggest ethnic minority in Mongolia, who provide education in their native language, Kazakh.

Second-language Instruction

There are a number of private or international schools that offer their classes, including mathematics and science classes, in different languages other than Mongolian.

Overarching Policies Related to Education and the Curriculum for Mathematics and Science

The mathematics and science curricula provide the criteria for making judgments about the learning process and describe what teachers at all levels should understand and be able to teach. With the development of the new curriculum and its implementation, starting in 2006, instruction changed from being teacher centered to student centered and now gives students more opportunity to create knowledge themselves, taking into consideration both social and individual needs. Teamwork, peer learning, and self-learning approaches are now encouraged in instruction.

The Mathematics Curriculum in Primary and Lower Secondary Grades

Summary of National Curriculum Guides for Mathematics Through Eighth Grade

Designed to enhance the capability of students to learn, reason, think creatively, make decisions, and solve problems, the mathematics curriculum helps students keep pace with technology and live in a democratic and competitive society and hold meaningful and productive jobs. The current curriculum was developed at the request of the Ministry of Education, Culture, and Science and approved by the National Center for Standardization in 2004.⁵ The education standards include introductory material, main

concepts, content standards, assessment standards, and methodologies and are based on four competencies of education: learning to know, learning to do, learning to be, and learning to live together.

The mathematics standards embody the ideal that students can understand mathematics through the four competencies of education. These require communication and physical and mental activity and allow students to apply estimation and mental arithmetic to real life, express their ideas logically, and understand the inter-relations of different problems and issues through modeling. The standards also are based on four content domains: numbers, algebra, geometry, and probability and statistics.

Communicating. Students will read, write, and speak properly and clearly in their mother tongue; communicate and describe concretely, pictorially, and symbolically and make models using pictures and symbols.

Reasoning. Students will understand and compare the inter-relations of various issues and phenomena through comparing, reasoning, and experiencing and make choices and conclusions based on concrete principles and reasons.

Modeling. Students will understand the main characteristics of different issues and identify their inter-relations and use estimation strategies to make models, conduct analyses, and implement solutions in real cases.

Problem solving. Students will identify problems, make hypotheses, formulate plans, and make good decisions.

The national curriculum guides for mathematics were developed with the goal of supporting the newly developed education standards. Since the education standards for mathematics were not developed for individual grades but for education levels, there have been some difficulties during implementation. Below is a brief description of each content area for fourth and eighth grades.

Grade 4

- *Number concepts:* read, write, represent, and describe numbers, as well as add, subtract, multiply, and divide; find the value of numerical expressions; read, write, add, and subtract like fractions; and solve word problems.
- *Algebra:* recognize relationships of components for operations including addition, subtraction, multiplication, and division; perform calculations using the properties of addition and subtraction to check results with different methods; find the area of rectangles and surface areas of cuboids; and provide interesting mathematics games such as dominoes, magic triangles, magic squares, and the chain game.
- *Geometry:* draw circles using a ball-bearing compass, then graph, name, and explain the center, radius, diameter, and sector; measure and draw angles using a protractor; differentiate units for height, weight, time, and area; draw, name, and explain cubes and cuboids, and draw a net of them; and find the area and calculate it for real-life scenarios.

- *Probability and statistics*: use result tables to understand regularities and patterns through observations and experiments; use reasoning to develop explanations; find random numbers to understand regularities; and find regularities through figures and continue them independently.

Grade 8

- *Number concepts*: understand rational and irrational number sets; add, multiply, and find powers and square roots for rational and irrational numbers; use the properties of operations; draw analogies and make conversions; conduct operations on integer degrees; and write numbers in standard figures and use them in different calculations.
- *Algebra*: simplify rational and irrational equations; find the solutions for square or rational equations and inequalities; square functions; understand, formulate and use the graph of a square function; make graphs for rational fraction numbers and learn their formulation; find and use the value or mean of functions; observe the general rules for finding integer degrees and form them into words or formulas; and use equations and equalization in problem solving.
- *Geometry*: categorize quadrilaterals, differentiate the elements, and find them in real-life environments, then draw, name and formulate them; formulate and use the Pythagorean theorem; find and formulate the correlation among lines, angles, triangles, and circles and use them for doing geometrical or practical sums; find the angles for 0° to 180° ; determine the sine, cosine, tangent, and cotangent and use their principles in practice; identify the conversion for geometric figures and parallel moves in words, graphs, figures, and formulas and use them as a communication tool; formulate, approve, and use figure conversions; find and use similar coefficients and similar figures; identify the characteristics of triangles; and conduct analyses on geometric figures using a ruler, a ball-bearing compass, or the coordinate method.
- *Probability and statistics*: make hypotheses and experiment on the operations for rules; know the practical usage of average, mode, and median for measurements; and identify correlations and regularities; and draw graphs and create models.

The Science Curriculum in Primary and Lower Secondary Grades

Summary of National Curriculum Guides for Science Through Eighth Grade

The development of the science curriculum relied on some key principles, such as equity, active learning, and improvement of the science education, considered important components of education reform. All students, regardless of age, sex, cultural, and ethnic background should have the same opportunity to obtain a science education.

The science curriculum in primary and lower secondary grades, approved in 2004, aims to teach students the social and cultural values of Mongolia as well as other countries through science education. The goal also is to increase the quality of science teaching and the system that supports proper planning, implementation, and monitoring. The

vision of this newly developed curriculum is to teach students to apply the knowledge and skills acquired through science education in their real lives, and not just memorize the terms and concepts passively.

As described in the primary education curriculum, science at the fourth grade is offered in two main domains, namely organic and nonorganic nature and natural phenomena. Through these two domains, students learn different topics such as organs, substances, the environment, and biological creatures.

In lower secondary education, or at grades 7–9, science is taught as separate subjects in biology, geography, chemistry, and physics. Content for science in each subject area is shown in Exhibit 1.^{6,7,8,9}

Exhibit 1 Science Content in Mongolia for Grades 7 to 9

Biology	Domain	Organ	Nature	Biological Creatures
	Content	Cell structure and processing Characteristics of living creatures Structure, categories, and characteristics of different organs	Nature and its regularities Environmental protection and rehabilitation Supporting the growth of plants and animals	Categories of different creatures Plants and animals and their peculiarities Role of plants, animals, and microorganisms in the nature
Geography	Domain	Man and the Environment	Correlation Between Nature and Society	Regions
	Content	Geographical location of Mongolia and its natural study Maps and their utilization The environment: its substructures and interrelations	Natural resources of the country and their proper usage, protection, and rehabilitation Naturally protected areas Changes in climate and environment: negative effects and approaches to combat them	Natural zones: their circumstances and ecological issues Diversity in Mongolian nature Basis on which to categorize the natural zones Maps of natural zones
Chemistry	Domain	Chemical Substances, Their Characteristics, and Reactions		
	Content	Chemistry study area Substances and their category Chemical substances and their characteristics Chemical reactions Kinds of chemical reactions Chemically mixed substances, water, and solutions		
Physics	Domain	Physics, Characteristics of Physics, and Physical Transformation and Energy		
	Content	Change of forces Heating Electric currents Magnets and magnetic attraction Electricity and light Sound and hearing		

In learning science, students describe objects and different phenomena or issues, ask questions, get answers, acquire knowledge, and provide explanations about these phenomena. Students also are engaged in problem solving, planning, group discussions, and peer learning, allowing them to explore further explanations and communicate their ideas to others.

Instruction for Mathematics and Science in Primary and Lower Secondary Grades

Mathematics and science instruction take place in the classroom in different formats, such as lectures, seminars, or question and answer sessions, and are generally theory based. Each teacher is responsible for choosing different kinds of active study methods to include in a lesson plan. These may include KWL charts (what students *know*, what they *want* to know and what they *learned* after instruction), corner and inceptive methods, intellectual debate, observations, excursions, RAFT (*role, audience, format, and topic*) strategies, dispute, tests, analytical readings, and problem-solving methods according to the subject or topic taught.

Instructional Time

The Ministry of Education, Culture, and Science approves the instructional plan for each subject every school year. At the fourth grade, the school year consists of 34 weeks of instruction, out of which 136 hours are allocated to mathematics, and 68 hours are allocated to science. At the secondary level, students receive 35 weeks of instruction, 140 hours of which are committed to mathematics instruction and 262 hours to science instruction at the eighth grade. More specifically, science instructional time at the eighth grade is devoted to physics, chemistry, and biology. At the primary level, each period consists of 40 minutes of instruction, however, at the lower and upper secondary levels each period is 45 minutes. Depending on individual differences between schools such as social requirements and student needs, schools may organize “cram schools”, or provisional instruction in mathematics and science.

Instructional Materials, Equipment, and Laboratories

In connection with the implementation of the 11-year school system, the Ministry of Education, Culture, and Science organized a textbook development bid through which two to three textbooks were selected and used in different schools. Laboratories, libraries, and computer rooms for physics, chemistry, and biology are being established in most schools throughout the country.

Grade at Which Specialist Teachers for Mathematics and Science Are Introduced

Nonspecialist teachers teach mathematics and science to students in grades 1–5. However, from grade 6 on, specialist teachers teach all subjects, including mathematics and science.

Use of Technology

Although Mongolia is behind other countries in technology use and research, there is a high demand for the innovations provided by technology in education. E-learning materials and module training for teachers to implement the education standards are being organized within the Fast Initiative Track project, in cooperation with the Ministry of Education, Culture, and Science. In general, all schools are attempting to increase the provision of information and communication technology for students to support their creativity, critical thinking, and teamwork skills. For example, technological applications and products provide support in science education. Scientific experiments and research also rely on technology for the tools to support the understanding of natural phenomena.

Teachers and Teacher Education

Education and Training for Fourth and Eighth Grade Mathematics and Science Teachers

The Law of Education defines a teacher as, “the person who possesses both professional and research skills to provide young children and youth with the necessary knowledge and skills to educate them to be citizens with good moral and social behavior”. Each teacher’s daily workload is relatively heavy, requiring 6 to 8 hours of work. Regarding the gender of teachers, 80 percent of all mathematics and science teachers are female.

In Mongolia, graduates from higher educational institutions who have 4-year bachelor’s degrees are eligible to work as teachers of mathematics and science at the secondary level. Teachers at the primary level are trained through a teachers college within 2 years. All teachers must have teacher qualifications or certifications. On their own initiative, however, teachers may enroll in graduate degree programs, since they are not required to teach at the primary or secondary levels.

The Teacher Qualification Committee at the education department, in conjunction with the province and capital city governor’s proposal, awards teacher certifications and decides whether to remove a certification based on negative performance. Depending on a teacher’s performance and professional skills, special marks are made on a teachers certification. Those who have three or more unsatisfactory marks are required to leave the job. Teachers who receive high performance marks may be rewarded with such titles as “teacher with good methodologies”, “head teacher”, and “consultant-teacher”.

Fourth grade students are taught mathematics and science by teachers who completed teachers college, while eighth grade students are taught by specialist teachers who have a bachelor’s degree or higher. Science at the eighth grade is offered in separate subjects, namely chemistry, physics, and geography with specialist teachers. In connection with the recent decision to provide science as an integrated subject, teachers are being trained in this way. There are no special requirements for mathematics and science teachers, aside from the general requirements for all teachers in the country.

Schools can be categorized according to the administrative units of the capital city, province center, *soum* center (the administrative unit equal to a district), and *bagh* (the smallest administrative unit). In the local and remote areas, there is a shortage of

mathematics and science teachers, which is explained mostly by lower salary, lack of any supportive mechanisms, and poor infrastructure. The Ministry of Education, Culture, and Science supports the policy to provide professional development for teachers and organizes different kinds of activities, such as capacity building workshops, competitions among teachers focusing on professional skills, and olympiads centered around specialized subjects. The best teachers are appraised and honored by the government award called “Honored Teacher” or “People’s Teacher”. Similar to the government awards, the Ministry of Education, Culture, and Science also gives the awards “Best Educator” or “Diploma of Honor” to the best teachers. Furthermore, teachers who have worked for many years in the field are granted special allowances.

Teacher Professional Development in Mathematics, Science, and Technology

All teachers are required to participate in professional development every 5 years, for which they earn credits. Professional development is offered during the workday, in the evening or through correspondence training. The education research and methodology institutions, certified by the education department or teacher institutes and colleges, organize these workshops.

Teachers are required to attend trainings that introduce newly approved and amended laws and regulations. Aside from these, however, teachers participate in various professional development workshops at their own expense and based on their own interests. There also are nonformal workshops on new technology, pedagogy, curriculum or standards development, and publication of new textbooks, which are offered by other universities, institutes, and nongovernmental organizations.

Examinations and Assessments

National or Regional Examinations

The state examinations, or the grade completion examinations, are organized for fifth grade students at the primary level, ninth grade students at the lower secondary level, and 11th grade students at the upper secondary level. Student performance is judged in a standard way regardless of the type of school attended.

Students at the primary level must take examinations in mathematics and the Mongolian language. Students at the lower secondary level take examinations in mathematics, Mongolian language, and one additional subject of their choosing. Students at the upper secondary level complete examinations in mathematics, Mongolian language, science, and humanities.

The content of the state examinations should reflect the requirements of primary, lower secondary, and upper secondary standards. Primary education examination marks are recorded in student books, while the lower and upper secondary examination results are written on students’ lower secondary and upper secondary education certificates.

In addition to the state examinations, students are required to take outside assessments to evaluate their primary and secondary education performance on mathematics and Mongolian. Fourth grade students take a grade completion examination organized by

the school examination committee. A mathematics test is required both for fourth and eighth grade students, however, science is not required for fourth grade students, since an assessment is made in their quarterly marks. Eighth grade students also take science examinations in chemistry, physics, and geography.

Other Tests

There are two national level evaluations in Mongolia: an external assessment evaluating the overall quality of education and an assessment of student achievement, which is aligned with state and entrance examinations. The outside assessment is conducted by the State Monitoring Agency every 5 years at each school. The agency evaluates all factors that influence education quality, such as implementation of standards and curriculum requirements, the teaching and learning process, qualifications for teachers or school authorities, school management, and the learning environment. The outside assessment evaluates both teachers and students in each subject using specially developed tests. The student achievement test is offered in some pilot areas as well.

Monitoring Individual Student Progress

Individual student progress is assessed and monitored through standard and nonstandard assessments. Nonstandard assessments are used in primary education and during the training process at all grades. Standard assessments are used for grade completion and for quarterly evaluations that use A–F letter marks. An A is given for high achievement, equal to 90 to 100 percent. A grade of B is given for higher than middle level achievement, equal to 80 to 89 percent and a C is for mid-level achievement, equal to 70 to 79 percent. A mark of D is for lower than mid-level achievement, but still meets the requirements for the standard and is equal to 60 to 69 percent, while an F is for low level of achievement or unsatisfactory, equal to 59 percent or below. All these marks are written in student books and lower and upper secondary education certificates and are used to encourage students' achievement and learning activities.

Grade Promotion and Retention Policies

Students take state examinations at the last grade in each level of education. This means fifth grade at the primary level, ninth grade at the lower secondary level, and 11th grade at the upper secondary level. At all other grades in between, students take grade completion examinations. Students who fail the examination or who do not perform up to the standard accomplishment requirement may stay in the same level of education for the next school year or are required to study on their own to meet the standard requirements. This policy is regulated at the individual school level.

Suggested Readings

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- 2 Primary and Secondary Education Law, Article 7-2
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- 6 Ministry of Education, Culture, and Science. (2004). *Biology curriculum guides*. Ulaanbaatar: Author.
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Morocco

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Introduction

Overview of Education System

Morocco's Constitution guarantees every citizen the right to an education.¹ Moreover, laws, decrees, and circulars (administrative documents) regulate education in the country. Providing education within the framework governed by these laws, decrees, and circulars, the Ministry of National Education, Higher Education, Staff Training, and Scientific Research directly administers all national educational institutions, allocates resources, and supervises universities, academies, and delegations. There are 14 universities in Morocco, in addition to a large number of private higher education institutions. Regional Academies in each of the 16 administrative regions of Morocco are charged with, among other things, developing 30 percent of the school curriculum, reflecting the decentralized nature of the education system in Morocco. *Délégations* are charged with, among other things, providing services for education in their regions.

The ministry is in compliance with recommendations laid down in the National Charter for Education and Training, which was adopted unanimously in 1999. The Charter recommended decentralized education delivery and increasing responsiveness to local needs and realities. The implementation of the National Charter for Education and Training has resulted in renewing the curriculum and textbook assessment and evaluation. The Directorate of Curricula develops the core curriculum, establishes pedagogical standards, and adopts textbooks in accordance with the guidelines and specifications established by the ministry. The guidelines devised by the directorate are used as a frame of reference in teacher training and the development of teaching materials.

According to the National Charter, preprimary education is compulsory and available to all children under the age of 6. There are two main types of preprimary schools in Morocco. The first type is kindergarten, which is a private school that provides education particularly in cities and towns. The second type is the Koranic school, which prepares children for primary education by helping them develop basic literacy and

numeracy skills. Koranic schools have the potential to become a major force in the fight against illiteracy.

Primary education is 6 years, and lower secondary education is 3 years. This type of education is provided through what is referred to as the “*Collège*”. After 9 years of basic education, students begin upper secondary school and take a 1-year common core curriculum, which is either in arts or science. First year students take arts or science, mathematics, or original education. Second year students take earth and life sciences, physics, agricultural science, technical studies, or are in the A or B mathematics track.

Language and Population

Morocco’s official language is Arabic.² Amazigh is spoken throughout Morocco and taught in primary schools. About one third of the population speak Amazigh. French is the medium of instruction of some technical disciplines in some upper secondary schools, universities, and institutes. French is introduced into the curriculum in the second grade of primary school. Foreign languages such as English (which is increasingly becoming the second foreign language of choice for youth), German, Italian, and Spanish are introduced into the curriculum in the third year of lower secondary schools. Arabic is the medium of instruction for mathematics and science in the fourth and eighth grades.

Overarching Policies Related to Education and the Curriculum for Mathematics and Science

Central to the vision of the National Reform for Education and Training, which is underway with regard to primary and secondary science education, is to move towards a knowledge-based society that is powered by information technology and, by extension, to prepare the new generation to meet the challenges of globalization and technological development. Hence, there is an obvious need to be able to think creatively, learn independently, and integrate successfully within groups or teams. The curriculum in mathematics and in science, laid down in the White Paper,³ draws upon the tenets of the competency-based approach and the value-based approach.

The Mathematics Curriculum in Primary and Lower Secondary Grades

Summary of National Curriculum Guides for Mathematics Through Eighth Grade

The **fourth grade** mathematics curriculum is geared towards students being able to do the following.

- Enjoy learning through practical activities
- Gain confidence and competence in the use of numbers and number systems
- Develop problem-solving ability
- Explore shape and space within a range of meaningful contexts
- Develop students’ measuring skills in a range of contexts
- Develop insights into the importance of mathematics in a growing number of occupations and in daily life.

The fourth grade syllabus for mathematics is organized around the following areas.

- Place value: numbers up to 999,999 (addition, subtraction, multiplication, division, and mental calculation strategies)
- Measurements in length, weight, time, capacity, and volume
- Geometry (basic geometric patterns, rectangular and square, symmetry, patterns, rotational symmetry, and tessellations).

The goals of the **eighth grade** mathematics curriculum are to enable learners to do the following.

- Acquire and apply the skills and knowledge pertaining to number, measure, space, and statistics necessary for use in everyday mathematical situations
- Acquire mathematical knowledge and skills necessary for future mathematics studies
- Develop the ability to make logical deduction and induction through solving mathematical problems
- Acquire oral and written language to communicate mathematical ideas and arguments clearly
- Develop a positive attitude toward, confidence in, and enjoyment of mathematics
- Develop the ability to monitor and evaluate their own progress appropriately
- Develop the skills necessary to plan and carry out a project.

The syllabus content of mathematics for the eighth grade includes the following components.

- Numerical operations of rational numbers, powers of a real number, and literal equations
- Statistical activities (not including linear functions)
- Geometry (axial symmetry, the Pythagorean theorem, the cosine of an angle, vector equality, and vector addition).

The mathematics syllabus content for both grades reflects continuity between primary and secondary education and, therefore, enables students to strengthen previously learned concepts and skills and develop further concepts and skills. It also enables them to further strengthen their mathematical thinking.

The Science Curriculum in Primary and Lower Secondary Grades

Summary of National Curriculum Guides for Science Through Eighth Grade

The goals of the **fourth grade** science curriculum are as follows.

- Provide students with experiences that build upon their interest in and stimulate their curiosity about our environment

- Help them gain deeper insights into themselves and, by implication, gain aesthetic appreciation of the natural world around them
- Help students develop scientific inquiry skills, attitudes, and values
- Help them recognize and use scientific knowledge and methods in making personal decisions
- Maximize their understanding of the influence that science and technology has on our environment and our lives.

The syllabus for fourth grade science revolves around the following topics.

- Gases (types of gases and common properties of gases)
- Nutrition, meals, and principles of digestion
- Motion, especially adaptations of animals living in water
- Measuring matter and physical and chemical changes
- The life cycle, with insects, and plants as models
- Classification of animals
- Flowering plant families
- Water and the environment, water use/water conservation, pollution, and living beings in nature
- Electricity and how electric circuits work.

The **eighth grade** science curriculum is designed to enable learners to develop a deeper understanding of science, the abilities and skills relevant to the study and practice of science, and skills such as objectivity, concern for accuracy, perseverance, and critical analysis. The distinguishing feature of the content of this syllabus for this grade is that it focuses equally on both the acquisition of scientific knowledge and thinking processes. It is organized around the following areas.

- The theory of plate tectonics, evidence supporting the movement of continents, geological phenomena, earthquakes, volcanoes, tectonic processes resulting in the formation of rocks/mountains, and the Earth System
- Animal reproduction, fertilization, continual development, and the concept of development cycle
- Plant reproduction and its processes
- Reproductive systems and their functions, pregnancy, delivery and breast feeding, and birth control
- Heredity, hereditary characteristics and diseases, and the role of spermatozoids in the transmission of hereditary characteristics
- The genetic ill effects of intermarriage among blood relatives
- Cloning.

Instruction for Mathematics and Science in Primary and Lower Secondary Grades

In Morocco, the instructional time for mathematics and science in grades 4 and 8 is shown in Exhibit 1.

Exhibit 1 Instructional Time for Mathematics and Science in Grades 4 and 8 in Morocco

Level	Mathematics	Science
Grade 4	Two lessons per week, each lasting 2 1/2 hours 5 hours of class per week 1 hour for remedial work 1-hour assessment/tests	Two sessions a week, each lasting 45 minutes
Grade 8	4 hours a week (as opposed to 5 hours in 2005)	28 hours per semester; each content area is covered in at least 2 hours and up to 8 hours, depending upon its value and/or length

Instructional Materials, Equipment, and Laboratories

Teachers of mathematics and science across the country use textbooks approved by the Ministry of National Education, in compliance with a book of specifications issued by the ministry. Teachers can supplement the textbooks with materials especially designed to further respond to students' specific needs. These materials are designed by inspectors or supervisors.

Grade at Which Specialist Teachers for Mathematics and Science Are Introduced

Specialist teachers in mathematics and science teach these subjects in lower secondary schools.

Use of Technology

Decision-makers at the Ministry of National Education are keenly aware of the importance of information and communication technology in education. They emphasize the development of policy guidelines and strategies for the integration of appropriate technologies in teaching and teacher professional development or growth. This has resulted in the national project, Generalization of New Information Technologies for Education, which is aimed at equipping schools with information and communication technology by the year 2009.

Homework Policies

Homework assignments are prioritized within schools and are geared toward helping students build responsibility, self-discipline, learner autonomy, and lifelong learning habits, and reinforcing learning outcomes. Homework assignments include practice tasks or activities, a preview of assignments, extension assignments, and creative activities.

Teachers and Teacher Education

Education and Training for Fourth and Eighth Grade Mathematics and Science Teachers

The Teacher Training Center for Primary School Teachers (*Centre de Formation des Instituteurs*) and the Regional Pedagogical Centre (*Centre Pédagogique Régionale*) for lower secondary school teachers provide full-time courses and a practicum leading to a professional graduate certificate in education. In order to be admitted to the 1-year preservice teacher education program, applicants are selected using a merit-based system. The selected applicants in either teacher college must hold a General University Studies Diploma (*Diplôme d'Etudes Universitaires Générales*), take and pass a written examination, and have a background interview. The General University Studies Diploma is a university diploma (Baccalaureate and 2 years at a university). Upon the successful completion of the course, teacher trainees at the two teacher colleges are appointed to primary and lower secondary schools, respectively. Preservice teacher training programs generally are broken into two major areas.

- Foundational knowledge about specific issues related to the philosophy of education, education psychology, and the sociology of education
- Methodologies for the teaching of content areas.

These programs include practicums primarily intended to provide hands-on experience in teaching.

Teacher Professional Development in Mathematics, Science, and Technology

The National Charter for Education and Training prioritizes professional development of teachers and school administrators. Teacher training colloquia and seminars are conducted by pedagogical inspectors within the 16 academies across the country with a view toward further enhancing teaching practices. Pedagogical inspectors play an important role in the education system in Morocco. They design teacher professional development programs and supervise teachers, among other endeavors, to further enhance teaching and learning.

Examinations and Assessments

National or Regional Examinations

The Ministry of National Education in Morocco has implemented policies that require students to pass exit examinations in order to obtain a higher certificate and, by implication, continue to the next level. Three types of formal exit examinations are administered at each educational cycle.

- **A primary school exit examination across the provinces.**⁴ Students are required to pass this examination to be eligible for admission into lower secondary schools. The primary cycle of education, which lasts 6 years, is sanctioned by a diploma.
- **A lower secondary exit examination across the regions.** Successful students are awarded a certification and are eligible for enrollment at upper secondary schools.

- **The Baccalaureate, a national achievement examination.** This examination takes 3 or 4 days to complete and draws upon the content and objectives laid down in the syllabi for upper secondary education. Varying depending on the nature of streams and tracks taken by students, the Baccalaureate does not test all content areas taught at school. Some of these are tested through continuous assessment at the end of either the first or second year Baccalaureate and in the regional Academie, an examination in the second term of the first year Baccalaureate. Students who achieve an overall average of 10 or better on a 20-point scale are awarded the Baccalaureate diploma. The National Charter for Education and Training, adopted in 1999, stipulates that all students who pass the Baccalaureate examination are eligible (in the year in which they pass the examination) for tuition-free studies at one of the public universities across the country.

Monitoring Individual Student Progress

Teachers use and rely on continuous assessment to monitor students' learning outcomes in accordance with the circulars and pedagogical guidelines on the content, frequency of administration, test duration, and weighting at each level. Continuous assessment tasks are curriculum based.

Continuous assessment is an important source of feedback to teaching and learning. Continuous assessment is geared towards helping teachers gauge the effectiveness of their teaching strategies in relation to the curriculum and accommodate their teaching styles to their students' learning. It also helps students develop a positive attitude toward mathematics and science, improving the teaching of such subjects. The Ministry of National Education has designed examination specifications and frames of reference for all stakeholders. Primary and lower secondary examinations are devised by commissions of experienced teachers and inspectors at the *délégations* and the Academies, respectively. The Baccalaureate examination is developed at the National Centre for Examinations.

Teachers conduct these tests at the end of the first semester and the end of the year. These are school-based tests and are administered under formal conditions. Their purpose is to determine how well students have achieved the overall syllabus objectives for the semester or year. Semester tests are broad in coverage and assess a representative sample of the syllabus covered during the semester or year and reflect its focus.

Grade Promotion and Retention Policies

The dropout rate has declined, particularly for primary school students. Also, retention rates have decreased considerably. An automatic promotion from one grade to the next has been instituted within primary schools. The requirements for definite promotion from lower secondary to upper secondary are fulfilled when the student achieves an average mark of 10, as stipulated by the National Charter for Education and Training.

Suggested Readings

For further details about the pedagogical guidelines for science and science test specifications applied in primary and lower secondary schools, go to www.men.gov.ma.

National Reform for Education and Training:
www.cosef.ac.ma

References

- 1 Constitution of Morocco, Article 13 (adopted on September 13, 1996): "All citizens shall have equal rights in seeking education and employment."
- 2 "An Islamic and fully sovereign state whose official language is Arabic, the Kingdom of Morocco constitutes a part of the Great Arab Maghreb." (Preamble to the Constitution of Morocco, 1996).
- 3 The White Paper endorses proposals for the education reform in Morocco. See Pedagogical Guidelines for scientific subjects in Primary and Lower Secondary/ Test Specifications for Primary and Lower Secondary in the White Paper at www.men.gov.ma
- 4 Morocco is divided into 16 administrative regions, which are further divided into provinces and prefectures.



The Netherlands

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Introduction

Overview of Education System

Dutch schools traditionally have considerable autonomy. The Dutch education system is based on the principle of freedom of education, which refers to freedom of establishment, freedom of conviction, and freedom of pedagogical approach.¹ This means that each resident of the Netherlands has the right to establish a school, and schools (or school boards) can autonomously decide how and, to a large extent, when to teach the core objectives of the Dutch curriculum on the basis of their religious, philosophical, or pedagogical views and principles.

The Minister of Education, Culture, and Science is primarily responsible for the structure of the education system, schools' funding, inspection of schools, the quality of national examinations, and student support.² The administration and management of schools is decentralized and carried out by school boards. A school board is responsible for the implementation of the curriculum, personnel policy, admission of students, and the financial policy. A board can be responsible for one school or for a number of schools. The school board of public schools consists of representatives of the municipality. The school board of private schools often is formed by an association or foundation. However, both school types are funded by the central government and, to some extent, by the municipalities. The majority of the private schools are Roman Catholic or Protestant, but there also are other religious schools and schools based on philosophical principles. The pedagogical approach of a small number of schools is based on the ideas of educational reformers such as Montessori, Helen Parkhurst (Dalton education), Peter Petersen (the Jenaplan schools), Célestin Freinet (the Freinet schools), and Rudolf Steiner (the Waldorf schools).

In order to meet certain quality standards, schools are visited at least once every 4 years by the Dutch Inspectorate for Education.³ The inspectorate collects information on students' achievement and progress, learning materials, learning time, the pedagogical climate, the pedagogical approach, testing, evaluation and monitoring, and the way the

schools are dealing with differences between students in learning abilities, behavior, and background. Beginning in 2008, each school also has to inform the inspectorate each year about student achievement and the school's education policy. Schools not meeting the quality standards are visited more frequently.⁴ The inspectorate can apply sanctions to very weak schools. However, the final decision about whether or not a school should be closed is made by the Minister of Education, Culture, and Science.

The results of school visits by the inspectorate are reported back to the individual schools, the government, and the public. A summary of the results of school visits for each school (a school report) is published on the website of the inspectorate. Usually, the results also are published in the School Guide for parents, together with schools' educational policy, the curriculum, pedagogical views and approaches, and rules and regulations. Parents can use the information from this guide and from the inspectorate's school reports if they want to choose a school for their child.

In the Netherlands, preprimary education and primary education are offered at the same school. Preprimary education (kindergarten) is 2 years and has both a social and an academic function, although the real basics in reading, writing, and mathematics usually are taught from the first year of primary education. Primary education takes 6 years. Most children go to preprimary education when they are 4 years old, but the first year is not compulsory. Compulsory education starts the first day after the month a child becomes 5 years old and ends after the school year in which the student becomes 16 and obtains a diploma on ISCED level 3 (upper secondary education) or ends after the school year in which the student becomes 18.

Secondary education starts with 2 years of basic education, which is more or less the same for each student, although students are often grouped by their learning abilities. After basic education, students enroll in one of three different tracks, depending on their learning abilities and interests.

1. *VMBO* (prevocational secondary education) offers four different programs: a basic vocational, a middle-management vocational, a combined vocational and theoretical program, or a theoretical program. After *VMBO*, students may continue on to *MBO* (vocational secondary education) or *HAVO* (grade 9).
2. *HAVO* (senior general secondary education) offers four different programs: science and technology, science and health, culture and society, or economics and society. After *HAVO*, students may continue with *HBO* (higher vocational education), *MBO*, or the last 2 years of *VWO*.
3. *VWO* (pre-university secondary education), offers the same four programs as *HAVO* but at a higher level. After *VWO*, students may continue with *HBO* or an academic study at a university.

Including the 2 years of basic education, *VMBO* is 4 years, *HAVO* 5 years, and *VWO* 6 years. *HBO* (usually 4 years) leads to a bachelor's degree. University education leads to a 3-year bachelor's degree. This can be followed by a master's degree, after completion of an additional 1 or 2 years at the university.

Language and Population

The official languages of the Netherlands are Dutch and Frisian. The latter is regarded as the second official language and is mostly spoken in the province of Friesland (Frisian is the mother tongue for 350,000 people). Dutch also is the official language for instruction at school, although a small number of Frisian schools are bilingual. Frisian is a compulsory subject for most primary schools in the province of Friesland. Some primary schools also teach a regional dialect alongside Dutch. A few secondary schools offer Frisian as an optional final examination subject.

About 10 percent of the whole population and 14 percent of the students in both primary and secondary education are part of a nonwestern ethnic minority.⁵ A student belongs to a nonwestern ethnic minority if one of the parents is born in Turkey, Africa, Latin-America, or Asia (excluding Indonesia and Japan). Most of the nonnative students come from Surinam, Turkey, and Morocco. Compared to native students and nonnative students from western countries, these students are overrepresented in the lowest track (*VMBO*) of secondary education.⁶

Emphasis on Mathematics and Science

The most important initiative to encourage students to pursue a mathematics or science related career is the *Platform Bèta Techniek*.⁷ Commissioned in 2004 by the government, its main goal is to increase the number of students who participate and finish higher (vocational) education in science or technology by 15 percent. The *Platform Bèta Techniek* targets schools, universities, businesses, ministries, municipalities, and regions. Currently, approximately 20 percent of the primary schools and secondary schools are involved in a project related to this platform.

The *VTB-Pro* Project of the *Platform Bèta Techniek* is targeted at primary school teachers. In this program, additional training in science and technology in an attractive, real-life context is provided for a total of 10,000 primary school teachers and students at teacher training colleges. The ultimate goal is not only to influence teachers' attitudes towards science and technology but also to make science and technology education more attractive to primary school students and increase students' self-confidence in these subjects, especially girls.

For secondary education, the platform offers the Universal Program. This project focuses on the low participation of secondary school students (girls specifically) in advanced mathematics and science courses. Research has shown that approximately half of all *HAVO* and *VWO* students with the potential to do their final examination in the Science and Technology or Science and Health programs, choose another examination program not related to science.⁸

Overarching Policies Related to Education and the Curriculum for Mathematics and Science

The Dutch curriculum for primary education is described as a set of core objectives to be taught (but not necessarily to be learned) by the end of primary education (grade 6). There also are core objectives formulated for the first 2 years of secondary education (basic education, grades 7 and 8).

Since August 2006, the set of core objectives for all subjects had been reduced from 115 to 58 core objectives to be instructed by the end of primary school.⁹ The new objectives are less detailed and should give schools more freedom in organizing their curriculum based on their pedagogical views. The core objectives for mathematics and the mother tongue are more specific than the objectives for the other subjects, such as science. There also are 58 core objectives for the first 2 years of secondary school.¹⁰

It is expected that schools will have implemented the new core objectives in their curriculum before August 2009. Schools and teachers can choose from a number of commercially developed instructional materials and teaching methods. Several independent institutes and organizations support schools with the implementation of the core objectives, such as the Freudenthal Institute for Science and Mathematics Education or The Dutch Institute for Curriculum Development. The latter provides advice and support for curriculum development and implementation in primary, secondary, and vocational education in all subjects, including mathematics and science. One of their activities is to translate the core objectives into more detailed indicators. Furthermore, they provide advice about the appropriateness of the different instructional materials and teaching methods for the Dutch curriculum. However, schools decide for themselves how to implement the core objectives and which learning materials to use. The Dutch Inspectorate for Education assesses to what extent the school curriculum guarantees the realization of the core objectives.

The Mathematics Curriculum in Primary and Lower Secondary Grades

Summary of National Curriculum Guides for Mathematics Through Eighth Grade

The mathematics curriculum for primary school is described in 11 core objectives. The basic principle is that during primary school, students should become familiar with mathematical basics that should be offered in a recognizable and meaningful context. Primary school students will gradually acquire familiarity with numbers, measurements, forms, structures, and the relationships and calculations that apply to these. They will learn to use mathematical language and gain mathematical literacy and skills in calculus.¹¹ The core objectives include the following.

- Use mathematical language
- Solve practical and formal arithmetical or mathematical problems and clearly represent argumentation
- Create approaches for solving arithmetical or mathematical problems and learn to assess solutions
- Understand the general structure and interrelationship of quantities, whole numbers, decimal numbers, percentages, and proportions, and use these to do arithmetic in practical situations
- Quickly carry out the basic calculations in their heads using whole numbers, at least to 100, so that they know how to add and subtract up to 20 and learn the multiplication tables

- Count and calculate by estimation
- Learn clever ways to add, subtract, multiply, and divide
- Add, subtract, multiply, and divide on paper
- Use a calculator with insight
- Solve simple geometrical problems
- Measure and calculate using units and measurements, such as time, money, length, circumference, surface area, volume, weight, speed, and temperature.

For the first 2 years of secondary school, the mathematics curriculum is described in nine core objectives.¹²

- Use appropriate mathematical language to order his or her own thinking, explain things to others, and understand the mathematical language of others
- Learn, individually and in collaboration with others, to recognize and use mathematics in practical situations to solve problems
- Set up a mathematical argumentation and distinguish it from opinions and allegations, thereby learning to give and receive mathematical criticism with respect for everybody's way of thinking
- See the structure and coherence of positive and negative numbers, decimal numbers, fractions, percentages, and proportions, and thereby learn to work in meaningful and practical situations
- Make exact calculations, provide estimates, and demonstrate understanding of accuracy, order of magnitude, and the margin of error appropriate in a given situation
- Measure, recognize the structure and coherence of the metric system, and calculate with measures for quantities common in relevant applications
- Use informal notations, schematic representations, tables, diagrams, and formulas to understand connections between quantities and variables
- Work with flat and three-dimensional forms and structures, make representations of them and interpret them, and calculate and reason with their properties
- Learn to systematically describe, order, and visualize data and critically judge data, representations, and conclusions.

The Science Curriculum in Primary and Lower Secondary Grades

Summary of National Curriculum Guides for Science Through Eighth Grade

In primary education, the subject, nature and technology, has seven objectives and is a subcategory of the main subject, personal and world orientation. This main subject can be described as: “pupils orientate on themselves, on how people relate to each other, how they solve problems, and how they give meaning to their existence.”¹³ The educational content of personal and world orientation is presented coherently, and content from

other learning areas is applied as much as possible. The core objectives for nature and technology include the following.

- Distinguish and name many common plants and animals in their own environment and the way they function
- Learn about the makeup of plants, animals, and humans and the form and function of their parts
- Research materials and physical phenomena, including light, sound, electricity, power, magnetism, and temperature
- Describe weather and climate in terms of temperature, precipitation, and wind
- Find connections between form, material use, and the way things work in their own environment
- Design, realize, and evaluate solutions to technical problems
- Learn that the position of the Earth in relation to the sun causes the seasons, as well as night and day.

In secondary school, the first year of science is part of the core objectives for the subject, man and nature, and contains eight core objectives in total.¹⁴ The core objectives for man and nature include the following.

- Transform questions arising from topics pertaining to the sciences, technology and care, and welfare into research questions; carry out an investigation on a scientific topic and present its results
- Acquire knowledge about and insight into key concepts of living and nonliving nature and connect these key concepts with situations from everyday life
- Learn that people, animals, and plants are related to each other and the environment and that technological and scientific applications can have permanent influences in a positive or negative way
- Learn, through practical work, to acquire knowledge about and insight into processes in living and nonliving nature, as well as their relation to the environment
- Work with theories and models through investigating phenomena from physical science and chemistry, such as electricity, sound, light, movement, energy, and matter
- Learn through investigation to acquire knowledge about technical products and systems relevant to him or her, estimate the value of this knowledge, and design and construct a technical product
- Understand the essentials of the build and function of the human body, establish connections with the promotion of physical and psychological health, and take his or her own responsibility in this respect
- Learn about how to care for himself or herself, others, and his or her environment, as well as how to influence his or her own safety and that of others in a positive

way in different situations of life (e.g., the living environment, learning, working, and going out into the world).

Instruction for Mathematics and Science in Primary and Lower Secondary Grades

Instructional Time

The minimum prescribed amount of total instructional time in preprimary (kindergarten) and primary education (grades 1 to 6) is 7,520 hours. On average, primary school teachers spend 5 hours per week on mathematics, and, on average, 1 hour per week on science.¹⁵ In the first 2 years of secondary education, students have 1,040 hours of instruction per year.

Schools can decide for themselves how much instructional time is devoted to the different subjects, how the instructional time is distributed over the different grades, and how to deal with homework. Although students in primary education are not expected to do homework, some primary schools give students homework to prepare them for homework in secondary education. In secondary education, homework is very common, but there is a huge variety between schools and teachers in the amount of assigned homework.

Instructional Materials, Equipment, and Laboratories

As stated before, the ministry does not prescribe the use of certain textbooks or other instructional materials (including the use of calculators or computers). Schools can choose from a number of commercially developed instructional materials and teaching methods, although some schools create their own materials. The Dutch Institute for Curriculum Development advises schools about the appropriateness of the available instructional materials and teaching methods for the Dutch curriculum.

Use of Technology

Since 1997, the implementation of information and communication technology (ICT) in education has been an important subject in the governments' educational policy.¹⁶ Almost every school uses computers for educational purposes, and, since 2002, each school is connected to the Internet. On average, there is one computer available for every seven students.¹⁷

Recently, the role of the government in stimulating ICT use has been taken over by the educational field itself. The foundations, Knowledge Net (*Kennisnet*) and ICT at Schools, are the main public support organizations for educational ICT use in primary, secondary, and adult education in the Netherlands. The goal of Knowledge Net is national and regional cooperation, with schools, branch organizations, and the government providing the technology. The mission of this foundation is "Learning to innovate with ICT and innovate learning with ICT."¹⁸

Grade at Which Specialist Teachers for Mathematics and Science Are Introduced

In primary education, mathematics and science usually is not taught by specialized subject teachers. A primary school teacher is trained to teach all subjects (except physical education) and all grades of preprimary and primary education. In secondary education, all teachers are subject teachers. As a consequence, teacher training for primary education and teacher training for secondary education are provided by different types of colleges.

Teachers and Teacher Education

Education and Training for Fourth and Eighth Grade Mathematics and Science Teachers

In order to qualify to be a primary school teacher, a diploma from one of the primary school teacher training colleges is needed.¹⁹ Primary school teacher training is provided at the higher vocational education (*HBO*) level and admits students with a *VWO*, *HAVO*, or a *MBO* diploma on the highest level. A primary school diploma usually takes 4 years to complete. At the end of the first year, students need to pass an examination in order to continue on to the remaining 3 years. First-year students also have to pass a mathematics and spelling test before they can continue with their course of study.²⁰

From the first year on, students get practical work experience during regular teaching practices at primary schools. About a quarter of the entire course is devoted to periods of teacher practices. Halfway through their teacher training, students can specialize in the younger child (kindergarten to grade 2) or older child (grades 3 to 6). However, each primary school teacher is allowed to teach all grades and all subjects in primary education, with the exception of physical education. Students in their final year of their training can be employed part time by a primary school for a maximum of 5 months.

Secondary school teachers are subject teachers.²¹ Most of these teachers are trained in one subject and general teaching at teacher training colleges for secondary education. Teacher training colleges admit students with a pre-university secondary education (*VWO*), senior general secondary education (*HAVO*), or a vocational secondary education (*MBO*) diploma on the highest level, into a program that fits their choice of subject. In the final year, students get practical work experience during a combined period of work and study at a secondary school as a trainee teacher. With a bachelor's diploma from a teacher training college, a teacher is a grade 2 teacher. These teachers are allowed to teach the lower grades (7, 8, and 9) of *HAVO* and *VWO* and all grades of *VMBO* and *MBO*. Grade 1 teachers often have a university degree (e.g., a master's degree in mathematics) with an additional master's degree in general teaching. This master's degree takes 1 year, approximately 250 hours is spent practicing teaching in a secondary school. For some subjects, teacher training colleges for secondary school teachers also offer additional training to become a grade 1 teacher. A grade 1 teacher can teach all grades in all tracks in secondary education, including *MBO*.

The school year 2006–2007 showed no real shortage of teachers, but it is expected that there will be a shortage in the very near future, especially in secondary education.²² The lack of mathematics and science teachers will be one of the biggest problems. The main reason is the age of the average teacher, which is 45 for almost half of primary school

teachers. For secondary education, 56 percent of teachers are 45 years or older and another 25 percent are 55 years or older. Also, teachers have a low interest in mathematics and science courses.²³ As a result of these issues, the current enrollment in teacher training colleges will not be enough to fill all future vacancies.

Teacher Professional Development in Mathematics, Science, and Technology

There is a huge variety of courses and other professional development activities for primary and secondary school teachers. Activities with regard to professional development are voluntary. It is up to the school or the teacher to take part in these activities.

There are courses in new teaching methods, remedial skills, dealing with students from different ethnic backgrounds, student monitoring systems, implementing core objectives, implementing information and communication technology, etc. As previously mentioned, the *VTB-Pro* Project provides training in science and technology for primary school teachers. Teacher professional development courses are offered by teacher training colleges, universities or (commercial) institutes, and organizations for educational advice and support. Furthermore, teachers can take part in subject-related workshops or conferences. There also are many digital journals, magazines, and newsletters (including for mathematics and sciences) available for teachers.

Examinations and Assessments

National or Regional Examinations

As stated before, schools can autonomously decide how and, to a large extent, when to teach the core objectives of the Dutch curriculum and when to assess students. Teachers usually will use tests that match the textbooks they are using for instruction.

In primary education, there are no national examinations. At the end of primary school, around 85% of schools use a multiple-choice test developed by *Cito* (the National Institute for Educational Measurement) in the mother tongue, mathematics, study skills (such as finding, using, and presenting information), and world orientation.²⁴ The results of these tests, together with advice from the school principal usually are used to determine the most appropriate track for the student in secondary education.

The final test by *Cito* also is part of a student monitoring system called *LOVS* (*Leerlingen onderwijs volgsysteem*). Besides the final test, *LOVS* consists of a test for grades 3, 4, and 5 in the mother tongue, mathematics, and study skills. Furthermore, there are regular tests in between subjects from kindergarten until grade 6, which enable the teacher and the school to monitor and improve the development of the individual student, as well as the class throughout the grades. The results of *LOVS* also are used by the Dutch Inspectorate for Education to assess the quality of the school.

Secondary education is concluded by national examinations in each subject in the last month (usually around May) in the final year (grades 10, 11, or 12, depending on the track). The content of these examinations is dependent on the track and the program of the student. *Cito* also has developed a student monitoring system for the first 3 years of secondary education, called *VAS*, for which students are tested regularly. Recently, this

system also included an instrument called *Studeon*, which is used for measuring the social-emotional development and learning motivation of students.

Grade Promotion and Retention Policies

Whether or not a student gets promoted to the next grade is determined by the school. Each school has its own procedures and rules for promotion and retention, which are usually described in the School Guide. The Ministry of Education, Culture, and Science tries to discourage retention, because it is assumed that retention would not really solve the problems of the student and decreases student motivation. An increasing number of secondary schools try to prevent retention as well by advising students to continue in a lower track or in a more suitable program.²⁵

In 2005, only 10 percent of all primary schools promoted all children to the next grade.²⁶ Most of the primary school students who repeated a grade were students in grades 1 and 2.

In 2005, approximately 5 percent of the students in secondary education were not promoted to the next grade.²⁷ The retention rate among boys is higher than that of girls, and the most problematic year (with the highest retention rate) is grade 10 of the senior general secondary education (*HAVO*) track, with 16 percent of the boys and 12 percent of the girls repeating a year in the same track or in the prevocational secondary education (*VMBO*) track.

Suggested Readings

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New Zealand

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Ministry of Education¹

Introduction

Overview of Education System

New Zealand has a decentralized system, with each school having the authority for its day-to-day running and financial management. Legal responsibility for governing schools is assigned to Boards of Trustees, which are comprised of elected parent and community volunteers, the school principal, a staff representative, and, in secondary schools only, a student representative. Boards of Trustees must establish a charter for their school and work within the framework of guidelines, requirements, and funding arrangements set by the central government.

There are six central agencies with responsibility for aspects of the education system: the Ministry of Education, the Tertiary Education Commission, the Education Review Office, the New Zealand Qualifications Authority, the New Zealand Teachers Council, and Career Services. Three of these bodies have responsibilities that relate directly to the curriculum: the Ministry of Education, the Education Review Office, and to a lesser extent, the New Zealand Qualifications Authority.²

The Ministry of Education has responsibility for developing national curriculum statements, resourcing education institutions, funding professional development programs, and providing operating guidelines. It also provides policy advice to the government, allocates funding and resources to education providers, oversees implementation of approved education policies, collects and processes education statistics and information, and monitors the effectiveness of the education system as a whole.

The Education Review Office evaluates the quality of education provided within each early childhood center and school, with the reports freely available to the public. This process ensures that schools are accountable for their financial management and that they adhere to their charter and government guidelines and regulations.

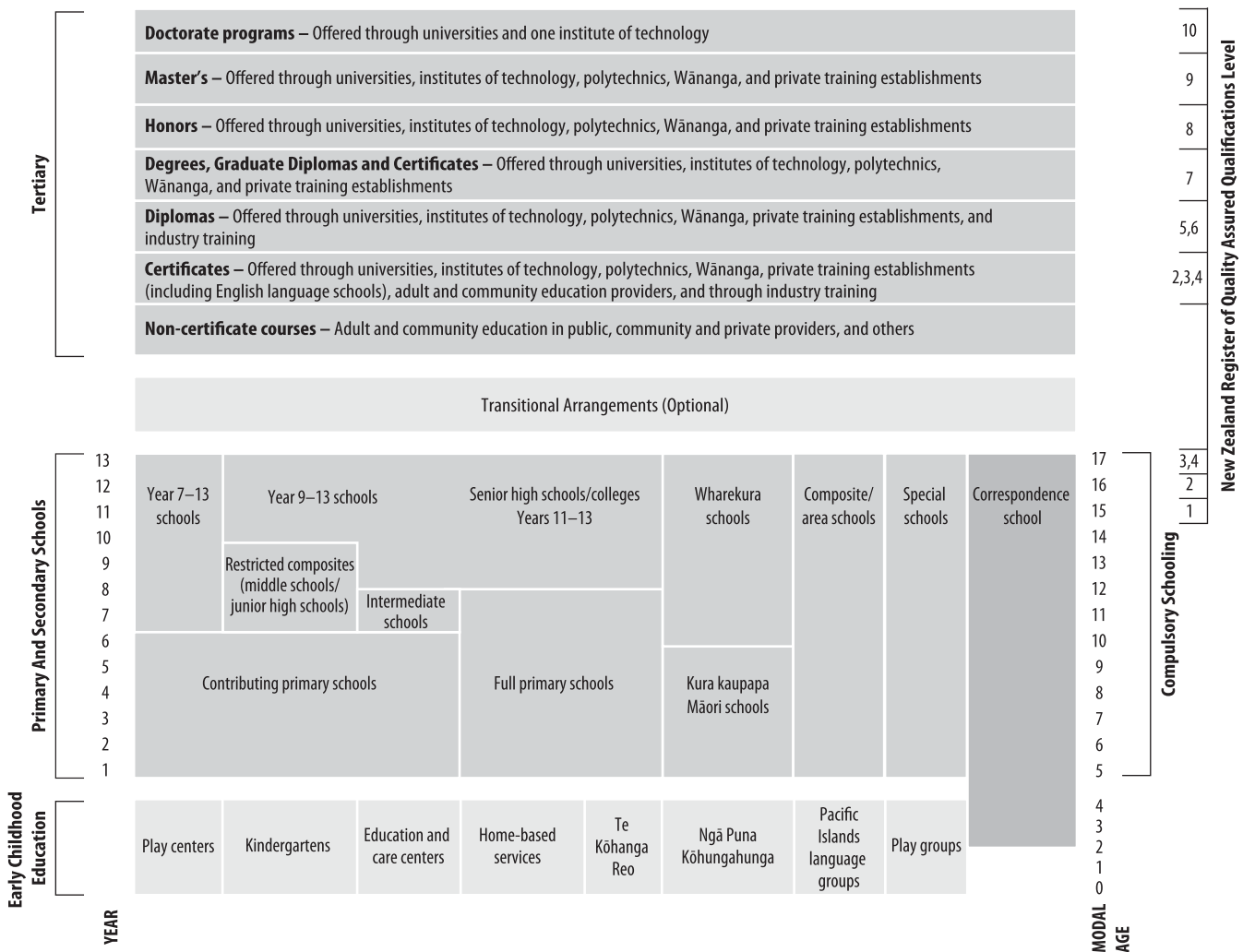
The primary function of the New Zealand Qualifications Authority is to coordinate the administration and quality assurance of national qualifications in New Zealand. In particular, it registers and monitors all national qualifications on the National

Qualifications Framework and runs New Zealand’s national senior secondary school examination programs.

While the Ministry of Education has the responsibility for developing national curriculum statements, schools and teachers decide how the curriculum is implemented, under the oversight from the Boards of Trustees. The Education Review Office monitors the implementation of the curriculum.

Exhibit 1 shows the structure of the education system in New Zealand. Participation in early childhood education in New Zealand is optional and available from birth, including a wide range of early childhood services. Most New Zealand preschool children attend some type of early childhood program for 17 hours per week, on average, with 90 percent of children who began school in 2006 reporting some early childhood education.³

Exhibit 1 Structure of the New Zealand Education System



SOURCE: Ministry of Education. (2007). *Education statistics of New Zealand for 2006*. Wellington: Author.

The primary function of early childhood education is social rather than academic. The principles of the Early Childhood Curriculum⁴ include the empowerment of children to learn and grow; the development of children holistically (i.e., cognitively, socially,

physically, emotionally, and spiritually); the importance of family and the community in children's development; and the importance of responsive and reciprocal relationships with people, places, and things in the development of children.

Schooling is available to children from age 5 and is compulsory from ages 6 to 16. The different types of primary and secondary schools differ only in the age range of children accepted rather than the course of study offered. There is no tracking of students in New Zealand schools.

Colleges of education, which were separate institutions in the New Zealand system, are now part of universities. Also, a small number of degrees are in excess of 3 years, and while the majority of students complete their schooling within 13 years, a smaller number continue to study in the school system for another 1 to 2 years.⁵

Language and Population

New Zealand has three official languages: English, Māori, and New Zealand Sign Language. Other languages commonly spoken in New Zealand include Samoan, Tongan, Cantonese, Mandarin, and Hindi.

The majority of New Zealand school children receive instruction in English.⁶ Three percent of students were enrolled in Māori-medium instruction in 2006 where at least 30 percent of teaching is in the Māori language; approximately half of these students have more than 80 percent of instruction in Māori. Of primary and secondary students, approximately 0.3 percent receive some instruction in a Pacific Island language.

The New Zealand population is becoming increasingly diverse ethnically.⁷ The majority of New Zealanders identify themselves as European (68%) or "New Zealanders" (11%), and the second largest ethnic grouping is Māori (15%). Both Asian (9%) and Pacific peoples (7%) are growing as a proportion of the New Zealand population. (Note: 10% of New Zealanders identified with more than one group.)

Second-language Instruction

The Ministry of Education provides additional funding for schools so that they can meet the needs of immigrant students and those New Zealand students from non-English speaking backgrounds who are learning English as a second language. Schools are responsible for the organizational arrangements required, which can range from entire classes with English language learning needs to only one child with a teacher aide or individual lessons with a specialist teacher. In general, most schools include students from non-English speaking backgrounds in general classes and make arrangements for additional help for those students requiring it.

Emphasis on Mathematics and Science

More emphasis is placed on reading and mathematics than science in primary schools. Specifically, the main area of focus for the Ministry of Education in primary schooling is on early foundations with an emphasis on literacy and numeracy, in particular, for Māori, Pasifika, and students with special education needs.⁸

Overarching Policies Related to Education and the Curriculum for Mathematics and Science

The TIMSS 1994–1995 findings highlighted areas of concern in mathematics and science education in New Zealand, primarily at the middle primary level. The release of these findings coincided with the period of implementing new curriculum documents, which teachers found difficult. Since then, a number of initiatives have been introduced, including developing mathematics and science resources for students and teachers, particularly in primary schools; research seminars to identify key issues in science and mathematics education; assessment tools for mathematics; and professional development programs focused on numeracy.

The Ministry of Education started developing a comprehensive numeracy policy and strategy in late 1998. By 2000, policy development initiatives focused on stages of early number development. “Count Me In Too” was piloted nationally as an action-research method of informing numeracy policy. The Numeracy Development Projects⁹ began in 2001, building on the evaluation findings from the pilot and the Exploratory Study professional development. The focus of these projects is on improving student achievement in mathematics through improving the professional capabilities of teachers.

A new curriculum document was launched in November 2007¹⁰ and will be gradually implemented into schools beginning in 2008, with full implementation by 2010. The new curriculum does not vary much from the old guides in terms of expectations for teaching mathematics and science content, and the old guides will be used as supporting documents for the new curriculum. Both the old and new versions split the mathematics and science learning areas into eight levels, with the levels specifying broad achievement objectives. From year 1 through year 13, students are expected to progress through the eight levels, but they can progress at different rates to address individual needs.

In general, the new curriculum places stronger emphasis on the values and competencies necessary for success in the 21st century, as well as recognizing current national and international developments in education, both in terms of academic and social outcomes. The new mathematics curriculum is now entitled *Mathematics and Statistics* to raise the profile of statistics.¹¹ It places greater emphasis on thinking rather than just doing, reflecting recent research and professional development initiatives that emphasize the importance of thinking mathematically and statistically. The mathematical processes, which were separated out from mathematical content in the old curriculum, have been integrated into the content areas to encourage this emphasis on thinking at all levels and across all content areas. In addition, the number and algebra strands, which were separate strands in the old curriculum, have been combined to reflect research showing that algebraic and arithmetical thinking are not discrete.

The Mathematics Curriculum in Primary and Lower Secondary Grades

Summary of National Curriculum Guides for Mathematics Through Eighth Grade

According to the national mathematics curriculum in place at the time of testing for TIMSS 2007, the majority of students should have been taught each of the following topics or skills by the end of **grade 4** (year 5).¹²

- *Number and algebra*: solve problems involving whole numbers and decimals that require a choice of one or more of the four arithmetic operations; recall basic addition, subtraction, and multiplication facts; estimate and check the reasonableness of answers; read and explain the meaning of the digits in whole numbers; order whole numbers (up to 100); order decimals with up to three decimal places; explain the meaning of the digits in decimal numbers with up to three decimal places; solve practical problems that require finding fractions of whole number and decimal amounts; make up and use a rule to create a sequential pattern; state the general rule for a set of similar practical problems; use symbols; continue and describe the rules for continuing sequential patterns; and use graphs to represent relations.
- *Measurement and geometry*: describe features of two- and three-dimensional objects; design and make containers to specified requirements; draw pictures of three-dimensional objects; draw and interpret scale maps; describe and interpret position; design, make, and describe geometric patterns involving translation, reflection, or rotation; enlarge on grid paper simple shapes to a specified scale; estimate and measure using the basic units of length, mass, area, volume, and temperature; use money, give change, and represent amounts; read and know the units of time; and convert between analog and digital time (and vice versa).
- *Statistics*: plan a statistical investigation; collect and display categorical and discrete numeric data (e.g., pictograms, tally charts, bar charts, etc.); talk about distinctive features, such as outliers and clusters, in data displays; make statements about what is represented by a statistical data display; use a systematic approach to count a set of possible outcomes; and predict the likelihood of outcomes on the basis of a set of observations.

According to the national mathematics curriculum, the majority of students should have been taught each of the following topics or skills by the end of **grade 8** (year 9).^{13,14}

- *Number and algebra*: explain the meaning and evaluate the powers of whole numbers; explain satisfactory algorithms for addition, subtraction, and multiplication; express quantities as fractions or percentages of a whole; convert fractions to decimals (and vice versa) and find fractions of quantities; find a percentage of a quantity; convert decimals to percentages (and vice versa) and solve problems using decimals and percentages; make sensible estimates, check the reasonableness of answers, and round numbers; demonstrate knowledge of the conventions of order of operations; convert numbers expressed in standard form to an ordinary form (and vice versa); explain the meaning of and solve problems involving negative numbers; share quantities in given ratios; continue a number sequence and write a rule to describe any member in it; use a rule to make predictions; graph linear rules on an integer co-ordinate system; evaluate linear expressions by substitution and solve linear equations; and combine like terms in algebraic expressions and factorize, expand, and simplify them.

- *Measurement and geometry*: calculate perimeters of circles, rectangles, triangles, etc. and composite shapes and volumes of cuboids, prisms, and cylinders from measurements of length; read a variety of scales, timetables, and charts; design and use a simple scale to measure qualitative data; read time, know units of time, and perform calculations with time, including the 24-hour clock; interpret and use information about rates; specify location using bearings or grid references; learn about the symmetry of regular polygons, including rotational and reflection symmetry; learn about transformations, including reflections, rotations, enlargements, and reductions; identify and use invariant properties under transformations; construct right angles and parallel and perpendicular lines, circles, etc.; and make isometric drawings of three-dimensional objects.
- *Statistics*: plan a statistical investigation; collect appropriate data; choose and construct quality data displays (frequency tables, bar charts, and histograms); collect and display time-series data; report outliers, clusters, and shapes of data displays; evaluate interpretations of data displays; make statements about implications and possible actions consistent with the results of a statistical investigation; estimate the relative frequencies of events and mark them on a scale; find all possible outcomes for a sequence of events using tree diagrams; and find data measures such as mean, median, mode, and range.

The Science Curriculum in Primary and Lower Secondary Grades

Summary of National Curriculum Guides for Science Through Eighth Grade

According to the national science curriculum at the time of testing for TIMSS 2007, the majority of students should have been taught each of the following topics or skills by the end of **grade 4** (year 5).¹⁵

- *Life science*: distinguish between living things within broad groups on the basis of their external characteristics; investigate special features of common animals and plants and describe how these help them stay alive; investigate and understand the general functions of the main parts of animals and plants; investigate and understand changes that take place in animals and plants during their life cycles; research and describe how some species have become extinct or are endangered; and investigate the responses of plants or animals and people to environmental changes in their habitats.
- *Physical science*: investigate and describe ideas about commonly experienced physical phenomena; explore and identify trends and relationships associated with observable physical phenomena; investigate and describe how items of everyday technology work and affect our lives; investigate and describe ways to group unfamiliar materials using readily observable properties; investigate and describe how the physical properties of materials are related to their use; investigate and report on temporary and more permanent changes that familiar materials undergo; use technology to demonstrate and explain methods that prevent or promote change in materials; and research the use and purpose of technology in disposing or recycling of some common materials.

- *Earth science*: investigate the major features that characterize Earth's water reserves (e.g., water cycle); present information about the origins and history of major natural features of the local landscape; locate and use information to learn about the general nature and behavior of the Earth, its Moon, and other planets in our solar system; investigate observable physical features and patterns and consider how they are affected by people; understand Earth's age and how animals and plants in the past were different; and justify their personal involvement in a school- or class-initiated local environmental project.

According to the national science curriculum, the majority of students should have been taught each of the following topics or skills by the end of **grade 8** (year 9).^{16,17}

- *Life science*: investigate and classify closely related living things on the basis of easily observable features; investigate and classify in broad terms the living world at a microscopic level; investigate and describe structural, physiological, and behavioral adaptations that ensure the survival of animals and flowering plants in their environment; use simple food chains to explain the feeding relationships of familiar animals and plants, and investigate the effects of human intervention on these relationships; and investigate and understand trophic and nutrient relationships between producers, consumers, and decomposers.
- *Physical science*: investigate and offer explanations for commonly experienced physical phenomena and compare their ideas with scientific ideas; process and interpret information to describe or confirm trends and relationships in observable physical phenomena; investigate and offer explanations of how selected items of technology function and enhance everyday activities of people; carry out simple, practical investigations with control of variables into common physical phenomena, and relate their findings to scientific ideas; describe various ways in which energy can be transformed and transferred in our everyday world; investigate how physical devices or systems can be used to perform specified functions; investigate and group common materials in terms of properties; investigate and explain how uses of everyday materials are related to their physical and simple chemical properties; investigate and describe ways of producing permanent or temporary changes in some familiar materials; investigate familiar substances and describe, using the concept of the particle nature of matter, how they may exist as solids, liquids, and gases; distinguish between elements, compounds, and mixtures, using simple chemical and physical properties and describe a simple model of the atom; and research and describe how selected materials are manufactured and used in everyday goods and technology.
- *Earth science*: investigate major factors and patterns associated with weather and use given data to predict weather; use simple technological devices to observe and describe our night sky and its changing patterns; investigate and use models that explain the changing spatial relationships of the Earth, its moon, and the sun, and the way different cultures have used these patterns to describe and measure time and position; and use information obtained from technological devices to learn about general characteristics of some near and far space objects.

Instruction for Mathematics and Science in Primary and Lower Secondary Grades

Instructional Time

There is no mandated instructional time in New Zealand schools. The findings from TIMSS 2002–2003 indicate that grade 4 (year 5) children typically have about 3.5 to 4 hours of mathematics instruction per week, and at the grade 8 level, students typically have about 3.5 to 4.5 hours of mathematics instruction per week.

In primary schools, science is generally taught as part of a topic that underlies a cross-curricular approach to teaching. On average, grade 4 (year 5) students would have about 1.5 to 2 hours of science instruction per week. At secondary schools, general science becomes a subject of study in its own right with a specialist science teacher, and students typically would have about 3.5 to 4.5 hours of instruction per week.

Instructional Materials, Equipment, and Laboratories

There are no mandated materials for mathematics and science instruction, however, the *Building Science Concepts* and the *Figure it Out* series of booklets are key resources for primary schools in science and mathematics, respectively. Free and supplied to schools by the Ministry of Education, the booklets suggest activities and associated equipment needed to undertake the activities, generally using easily available resources.

Other resources include videos, websites, and CD-ROMs to support the learning materials and show effective classroom practices. For example, the nzmaths website,¹⁸ the key Ministry of Education website for supporting mathematics teaching and learning, includes resources and a tool for planning lessons.

In general, laboratories only are available in secondary schools. The purchase of instructional materials and equipment is a school-based decision.

Grade at Which Specialist Teachers for Mathematics and Science Are Introduced

Generally, most students will have their first specialist teachers for mathematics and science in grade 8 (year 9). However, some students may have specialist teachers for these subjects in grades 6 and 7 (years 7 and 8). Also, where there are teacher shortages, some students may not have a mathematics or science specialist until they begin grade 10 (year 11), the first year of external examinations.

Use of Technology

Most New Zealand schools have computers available for use by students and teachers. A number of websites, including those sponsored by the Ministry of Education, contain resources suitable for student use. For example, *Te Kete Ipurangi*, the online learning center, is a “bilingual portal-plus web community that provides quality assured educational material for New Zealand teachers, school managers, and the wider education community.”¹⁹

Graphic calculators have become more widespread, particularly in senior secondary classes. Interactive whiteboards, also known as SMART™ Boards, are beginning to be used in schools, along with text messaging and personal digital assistants or PDAs.

Homework Policies

There is no policy to include homework as part of everyday student activities at a national level in New Zealand. However, the new curriculum has community engagement as an important principle, with the intention of engaging families and communities in the education of their young people.

Teachers and Teacher Education

Education and Training for Fourth and Eighth Grade Mathematics and Science Teachers

There are a number of paths to become a qualified teacher and a range of teacher education providers. In general, students spend at least 3 years in teacher training, either gaining a bachelor's degree (general areas of study for primary education and in the specialist subject for secondary education), followed by a Graduate Diploma of Teaching or a degree or diploma that combined bachelor-degree learning with training in teaching. All teacher education providers must have their programs approved by the New Zealand Teachers Council and practicum experience of at least 14 weeks is required.²⁰

While there are no specific requirements for time spent in particular subject areas, teacher education programs should provide learning opportunities that enable graduates to meet the Satisfactory Teacher Dimensions. Graduating students should demonstrate satisfactory achievement in each of four dimensions: knowledge of teaching and learning; promotion of the learning of students through good practice; the ability to maintain relationships of trust, cooperation, and respect in a school community; and providing educational leadership at a relevant level.

The New Zealand Teachers Council keeps a register of all qualified teachers. Upon becoming registered, a teacher is issued a practicing certificate, which must be renewed every 3 years. Teachers must satisfy certain requirements, including satisfactory completion of work as a teacher, endorsed by other staff within their school, to have their practicing certificate renewed. Teacher registration is mandatory for all teachers who are employed in schools in New Zealand.

Other than those requirements mentioned above, specialist mathematics or science teachers at the secondary education level are expected to have completed some tertiary level mathematics or science papers. Mathematics and the sciences are two of the five subject areas currently experiencing teacher shortages across the secondary schooling sector.²¹

Teacher Professional Development in Mathematics, Science, and Technology

Schools are responsible for ensuring that teachers participate regularly in some form of professional development. Also, it is expected, under the practicing certificate requirements,²² that some form of professional development will occur during the 3-year period prior to renewal of the certificate.

A number of professional development opportunities are available to teachers from different service providers, including in-class support for teachers and school-based programs facilitated by advisers, as well as a variety of externally facilitated programs. These range from 1-day workshops and seminars to part-time master's degree programs.

The School Support Services, based in either faculties of education or colleges of education in universities, are the main providers of professional learning programs offered by the Ministry of Education. Schools, colleges of education, and consultants also provide teacher professional development.

The Numeracy Development Projects to improve student performance in mathematics through improving the professional capability of teachers began in 2001, as previously mentioned. This initiative, however, was only available in a selection of schools in the first year of implementation and was gradually implemented into other schools over successive years, with some schools still not having participated by the time of testing for TIMSS 2007. Therefore, the majority of the population of grade 4 students (year 5) is likely to have had only a portion of their schooling with teachers who have undertaken professional development under this initiative.

Examinations and Assessments

National or Regional Examinations

The New Zealand Qualifications Authority is responsible for coordinating the administration and quality assurance of national qualifications in New Zealand. The National Certificate of Educational Achievement is the main national qualification for secondary students and is administered to students in grades 10, 11, and 12 (years 11–13). This test is designed to be flexible so students may take any combination of levels of courses depending on their abilities and previous attainments.

In each area of learning, different aspects of skills, knowledge, and understanding are assessed separately, with assessments designed to suit the skill or knowledge being assessed.²³ Schools also can offer a wide range of specialized National Certificates that may be a starting point for further study or simply broaden general education. Therefore, a variety of assessment tools, including presentations, assignments, practical tests, and examinations are used.

Other Tests

Four sources of standardized tests, either intact tests or single items, are available to schools as required. These sources include the Assessment Resource Banks, the National Education Monitoring Project, the Assessment Tools for Teaching and Learning, and the Progressive Achievement Tests.

The Assessment Resource Banks, designed for students in grades 3 to 9 (years 4 to 10), have been developed at the New Zealand Council for Educational Research, under contract to the Ministry of Education, to match New Zealand curriculum statements in English, mathematics, and science. They are provided to help teachers assess progress or judge the relative performance of their students against the typical performance of national samples of students at given year levels.²⁴ Teachers can choose from a variety of tasks, including both written and practical open-ended tasks, as part of their assessment program to match the students' learning context. The tasks are designed to be used with students from grades 3 to 9 (years 4 to 10).

Designed to monitor the education system in New Zealand, the National Education Monitoring Project assesses carefully selected random samples of students at grade 3 (year 4) and grade 7 (year 8) to measure attitudes and achievement at the system level (rather than at the student level). The Educational Assessment Research unit administers the assessments under contract to the Ministry of Education, covering the entire curriculum over a 4-year cycle.²⁵ Every year selected assessment tasks are released to the public, complete with scoring guides and the percentage correct results for the students. Teachers can use these tasks, which include written items, performance items, and group activities in their classrooms.

The Assessment Tools for Teaching and Learning is an educational resource for assessing literacy and numeracy at grades 3 to 11 (years 4 to 12), developed for the Ministry of Education by the University of Auckland.²⁶ Teachers can use this resource to create 40-minute paper and pencil tests designed for their own students' learning needs. Once the tests are scored, this tool generates interactive graphic reports that allow teachers to analyze student achievement against curriculum levels, curriculum objectives, and population norms.

The New Zealand Council for Educational Research, for ages 7 to 15, produces the Progressive Achievement Tests for schools in reading, mathematics, listening, and information skills. These are formative assessments, but may be used for comparative purposes, since each student's score can be converted to a stanine or percentile rank by class and age.²⁷

Monitoring Individual Student Progress

In New Zealand, schools are required to use a range of assessment practices to evaluate students' progress and achievement.²⁸ Education is recognized as a partnership between students, parents, teachers, and school communities.²⁹ As part of this partnership, schools should use assessment information to provide high-quality feedback to parents. Schools decide how and when feedback to parents happens.

Feedback to parents can occur in three different formats: written reporting, which may include the use of student portfolios, parent-teacher interviews, and three-way conferencing (parent-student-teacher). In some of these settings, particularly three-way conferencing, not only is the progress of a student reported on, but goals also are set for future work.

The use of grades and marks varies across schools and depends on the type of assessment and reporting used. For example, a portfolio might include a basic mathematical facts test with a score, while a report might include only a comment on progress with no grade attached.

Grade Promotion and Retention Policies

A major underlying premise in the New Zealand education system is that teachers and schools should meet the educational needs of individual students.³⁰ Students are promoted socially through the grades. At the primary level, the use of classes with

students from multiple grades (composite classes) is widespread and allows for students with a range of abilities in each class. The curriculum document recognizes that students are likely to progress at different rates through each curriculum area and might achieve objectives from different levels, so teachers are expected to adapt their teaching to the needs of students.³¹

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Norway

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Introduction

Overview of Education System

Norway has a centralized curriculum for all subjects in grades 1–13. The curriculum is approved by the parliament, based on a process initiated by the Ministry of Education in which expert groups develop proposals, followed by a hearing among teachers, teacher educators, and various institutions. Within the framework set by the curriculum, considerable freedom is given to local schools and teachers to make decisions on organization and instructional methods.

Kindergarten or preprimary school is neither compulsory nor free in Norway. However, the present government puts a high priority on making it available for all who want their children to attend.

Every Norwegian child has a legal right to 13 years of education. Children enter grade 1 in August during the calendar year of their sixth birthday. The first 10 grades are compulsory and free, hence, compulsory education ends at age 16. The next 3 years (grades 11 to 13 of secondary school) are not compulsory but still are free. The only exception has been textbooks, which until recently, secondary students have had to buy themselves. However, the government has decided to provide free textbooks in secondary education as well, a reform which will be fully implemented in 2009.

The Norwegian education system is divided into three main stages. In the first two stages, grades 1–7 are called the “child stage”, while grades 8–10 are called the “youth stage”. Together, these stages constitute compulsory school or **basic school**. The child stage and youth stage may be in separate schools or combined into one school. As a result of Norway’s scattered population, some schools are so small that students from different grades are taught together. In basic school, there is no streaming and very few options. Almost all students are taught together in their classes in all subjects.

The third stage, which includes grades 11–13, constitutes (upper) **secondary school**. Although this school is not compulsory, it is attended (or attempted) by the vast majority of youth. All students take certain basic subjects. However, they also choose

between a variety of vocational study programs and general programs that qualify for tertiary studies.

Most students are enrolled in public schools. Private schools are considered a supplement to public education. Only about 2 percent of students in basic school attend private schools. At the secondary level, the percentage is a bit higher.

A new upper secondary school curriculum¹ was introduced in 1994, R94 (Reform 1994), followed by a new curriculum for basic school² in 1997, L97 (Curriculum 1997). Both of these gave broad descriptions of content to be learned in each grade in every subject. The basic school curriculum was quite lengthy and gave detailed instructions on teaching methods to be used. In 2006, a new curriculum reform was introduced and was fully implemented beginning in 2008. This reform was strongly informed and influenced by Norwegian results on the TIMSS and PISA studies in 2003, where Norway scored below expectations. The reform is called Knowledge Promotion, or Ko6.³ It presents, for the first time, a comprehensive curriculum for the whole Norwegian school system. Basic educational visions from the previous curriculum have been retained.⁴ However, the goals no longer consist of lists of content or methods but rather are statements of competencies to be achieved. A new concept of basic skills has been introduced, and more time has been allocated to mathematics and science in the lower grades.

The Norwegian grade 4 participants in TIMSS 2007 were taught under the previous curriculum (L97) for 3 years and the new curriculum (Ko6) for less than a year. Similarly, grade 8 participants were taught under L97 for 7 years and Ko6 for less than a year. For this reason, this chapter mainly describes L97 and then provides some information on the most important and relevant changes in Ko6.

Language and Population

Norwegian, the main language spoken in Norway, has a variety of dialects. There are two standardized varieties of written Norwegian, *Bokmaal* and *Nynorsk*, which have been officially recognized for about a century. The majority of the population writes *Bokmaal*. Students have to learn to write both, and all textbooks and other instructional materials must be available in both languages.

In addition, the Sámi population speaks and writes three distinctive Sámi languages. In certain schools, Sámi is the language of instruction.

In Norway, all students in basic (compulsory) school have the right to be educated in their own language. Immigrant students may be taught both in their mother tongue and in Norwegian. English language is taught beginning in grade 1. For more information about languages in the Norwegian school system, see the *PIRLS 2006 Encyclopedia*.⁵

Emphasis on Mathematics and Science

Mathematics is one of the core subjects and has a strong position in the school curriculum. Mathematics also is a compulsory subject in the general teacher education curriculum in the university colleges. However, teacher education does not require specialization in mathematics beyond the compulsory course in grade 11 in upper secondary school.

The situation for science is different. Students receive much less instructional time in science than in mathematics during compulsory education. There also is no national written examination in science at the end of grade 10 as there is in mathematics. Moreover, science and science education are not compulsory subjects in the general teacher education programs in the university colleges.

The Mathematics Curriculum in Primary and Lower Secondary Grades

Summary of National Curriculum Guides for Mathematics Through Eighth Grade

Since the Norwegian students who participated in TIMSS 2007 mainly have been exposed to the L97 curriculum (see above), the following explanation will concentrate on this curriculum. Relevant changes in the new K06 curriculum are outlined at the end of this section.

Apart from describing the importance and usefulness of the subject, the introduction to the mathematics curriculum in L97 emphasizes concepts like creativity, inventiveness, and critical and analytical abilities. “As they experiment, experience, wonder and reflect, the subject will help to develop the pupils’ curiosity and urge to explore. It is important for pupils to experience the learning of mathematics as a process.”⁶ In addition, there is an emphasis on linking the subject to the learner’s world of experience and everyday life. “Mathematics must be firmly rooted in practical matters.”⁷ The practical applications, examples, and methods chosen are meant to ensure that girls and boys alike and students with different cultural and social backgrounds have the opportunity to experience a sense of belonging and develop favorable attitudes to the discipline.

The curriculum content is organized into main areas. For grades 1–4, these areas are mathematics in everyday life, numbers, and space and shape. For grades 5–7, the main areas are mathematics in everyday life, numbers, geometry, and handling data. For grades 8–10, the main areas are mathematics in everyday life, numbers and algebra, geometry, handling data, and graphs and functions.

The area, mathematics in everyday life, is prominent throughout basic (compulsory) school. The curriculum explicitly states that this main area “establishes the subject in a social and cultural context and is especially oriented towards users.”⁸ This perspective is even taken into the traditionally abstract area of algebra: “It is essential to place work with variables and formulae in meaningful contexts” and, similarly, “The formal aspects of algebra must be grounded in concrete examples.”⁹

The general goals for mathematics in basic (compulsory) school are for students to develop the following attitudes and skills.

- Develop a positive attitude toward mathematics, experience it as meaningful, and build up confidence in their own potential in the subject
- Find mathematics to be a useful tool at school, in leisure activities, and in their work and social lives
- Be stimulated to use their imagination, personal resources, and knowledge

- Develop skills in reading and formulating and communicating issues and ideas in which it is natural to use the language and symbols of mathematics
- Develop insight into fundamental mathematical concepts and methods, develop an ability to see relations and structures, understand and use logical chains of reasoning, and draw conclusions
- Develop insight into the history of mathematics and its role in culture and science.

The curriculum has lengthy and detailed lists of objectives for each grade. The objectives specify both the content to be learned and activities or methods to be used in class. Verbs that are frequently used illustrate the latter point: experience, practice, work, make, collect, arrange, apply, experiment, investigate, examine, explore, discover, compare, record, describe, formulate, illustrate, cooperate, discuss, and interpret.

The objectives progress from a rather playful and simple approach in grade 1 to a more traditional approach in the upper grades.

The content to be covered by the **end of grade 4** is the following.

- Students shall have had practical experiences and solved practical problems in everyday situations, such as buying and selling and taking measurements. They shall have collected data and illustrated them by simple diagrams.
- Students shall have learned natural numbers, digits, and place value; developed skills in adding, subtracting, multiplying, and dividing natural numbers; and worked with negative numbers, simple fractions, and decimal numbers in practical situations.
- Students shall have worked with figures in 2-dimensional plane and 3-dimensional space, sorted and described them, and learned names for important shapes; studied positions in reference grids and motion, reflection, and rotation of figures; and measured lengths and angles, calculated simple areas and volumes, and learned standard units for these.

The content to be covered by the **end of grade 8** is the following.

- Students shall have gained experiences and performed calculations with distance, speed, volume, weight, time, calendars, time schedules, food, nutrition, travels, telephone bills, stamp duties, the economy, prices, discounts, salaries, savings, interest rates, budgets, and currencies, and made simple use of spreadsheets.
- Students shall have continued working with place value, decimal numbers, and negative numbers, using all four basic arithmetical operations; calculated with fractions and percentages; practiced making estimates and doing mental arithmetic; worked with prime numbers, factorization, square numbers, and square roots; and explored number patterns and developed understanding for the use of letters and parentheses in simple expressions and formulas.
- Students shall have made figures, shapes, and patterns (including circles, prisms, and cylinders), explored their properties, measured lengths, and calculated circumference, area, and volume; studied localization and movement in

coordinate systems and maps and worked with map scales; constructed parallels, perpendiculars, angles, and geometrical figures; worked with symmetries of simple shapes and explored regular polygons; and investigated geometrical patterns, such as covering a plane with polygons.

- Students shall have collected, organized, discussed, and interpreted data and presented them in tables and simple diagrams; learned how to find the median, mode, mean, and variance; and described probability in practical situations from everyday life and games.
- Students shall have worked with points and coordinates in coordinate systems; made graphs describing situations and relations in everyday life; and understood the function concept as a useful tool.

The important changes in the new curriculum, Ko6,¹⁰ make it shorter and less detailed than L97. It sets objectives for competencies but gives no regulations for instructional methods. Five types of basic skills have been introduced: oral skills, writing skills, reading skills, digital skills, and numeracy. They are to be applied and developed in every subject at every level.

The mathematics curriculum for basic (compulsory) school is again organized into main areas. For grades 1–4, these areas are numbers, geometry, measuring, and statistics. For grades 5–7, the main areas are numbers and algebra, geometry, measuring, and statistics and probability. For grades 8–10, the main areas are numbers and algebra; geometry; measuring; statistics, probability, and combinatorics; and functions.¹¹

The most remarkable changes from L97 are the following.

- Less emphasis on mathematics in an everyday context (this no longer constitutes a main area, but the perspective is still integrated into most areas of the curriculum)
- Stronger emphasis on knowledge and less emphasis on activities
- Algebra and probability are introduced earlier.

Moreover, under the new curriculum, more instructional time is allocated to mathematics than before in the lower levels (child stage). Also, while L97 had specific objectives formulated for each grade, Ko6 only has objectives for each stage (grades 1–2, 3–4, 5–7, and 8–10). This, among other things, gives more organizational and pedagogical freedom to schools.

The Science Curriculum in Primary and Lower Secondary Grades

Summary of National Curriculum Guides for Science Through Eighth Grade

Since the Norwegian students who participated in TIMSS 2007 mainly were exposed to the L97 curriculum, as mentioned previously, the following explanation will focus on this curriculum. Relevant changes in the new Ko6 curriculum are outlined at the end of the section. In L97, the subject was called “science and the environment”.

The curriculum emphasizes the pivotal role played by science and technology in modern society. “They can help us to achieve better health and to live meaningful and

dignified lives. But if science and technology are misdirected, they can harm nature and the environment and destroy the living conditions of future generations.”¹² Hence, it is important that everyone have basic knowledge about nature and various technologies and how these transform nature. The subject intends to help students acquire adequate knowledge, skills, and attitudes needed to become active citizens and participate in sustainable development.

Sense perception, observation, classification, experimentation, and fieldwork are considered fundamental in learning the subject. Students shall carry out inquiries outdoors, in the classroom, or in the science room. The examples and methods employed must bring out the experience of girls and boys equally. Attention is focused on students' everyday experience in their local environment before they begin to adopt a more global perspective and can approach various scientific topics more systematically. Health and lifestyles, changes in the greenhouse effect and the ozone layer, genetic engineering, and resource management are included. Some key words are wonder, observation, systematic investigation, classification, connections, and discussion.

At all stages, everyday life experiences of the students are emphasized. The need for developing students' sense of care and responsibility for the natural environment is similarly emphasized. Observation and experiments are essential throughout.

The curriculum content is organized into four main areas. For all 10 grades, these areas are the human body and health; natural diversity; substances, their properties and use; and the physical world.

The general goals for science and the environment in basic (compulsory) school are that students develop the following attitudes and skills.

- Knowledge, skills, and attitudes that help them enjoy their experiences with nature and give them opportunities to develop imagination, creativity, and an interest in exploring their surroundings.
- Knowledge of various substances and their properties and use to enable them to see connections and make environmentally friendly choices in their daily lives as well as to develop insight into technology and various physical phenomena, which may inform their participation in society.
- Insight into natural relationships and the interplay between man and nature, so that they can contribute to sustainable development and develop knowledge and attitudes that will enable them to look after their own bodies and health and show care and respect for others.
- Knowledge about and practice with scientific thinking and methods, knowledge of some important scientists, and acquaintance with the impact of science and technology on the development of society.
- Experience in the use of tools, experimental equipment, and electronic aids in a broad range of activities.

The curriculum has lengthy and detailed lists of objectives for each grade. The objectives specify both the content to be learned and activities or methods to be used in class.

The content to be covered by the **end of grade 4** is the following.

- Students shall have stimulated their senses, learned how the body functions, and learned some basic facts about diseases and how to care for one's own health.
- Students shall, through experience, have developed a positive attitude, a sense of curiosity, and a respect for the rich diversity of nature, as well as a sense of care and responsibility for the natural environment in their neighborhood and studied some plants, trees, animals, birds, and rocks in their neighborhood.
- Students shall have built up knowledge about various substances and some of their properties; examined floating and sinking, freezing, and melting and evaporation; and learned about recycling and environmentally friendly treatment of waste.
- Students shall have learned about some everyday physical phenomena, such as light, sound, weather, the seasons, the solar system, forces and motion, gravity and levers, and friction.

The content to be covered by the **end of grade 8** is the following.

- Students shall have knowledge about some bodily functions, such as digestion, the eye, and the ear, and examples of similarities and differences between man and other animals; worked with questions related to puberty and sexual identity; understood the value of a healthy diet, learned about effects of tobacco and drugs, and developed attitudes about the use of toxic substances; and learned about bacteria, diseases, and medicine.
- Students shall have done systematic observations in various biotopes and thus developed understanding of the interplay in nature and respect for its diversity; learned about common animals, plants, and fungi, as well as some endangered species; worked with food chains and photosynthesis; and studied the physical preconditions for life on Earth, examples of how living organisms are adapted to various climatic conditions, and the main features of the theory of evolution.
- Students shall have learned properties of selected substances and their applications in everyday life and become acquainted with common metals, minerals, and rocks; experimented with combustion of materials and gained insight into the role of water in nature and society; planned and carried out experiments for separating a substance from a mixture; studied the concept of pH and methods of determining pH values; learned the principal properties of oxygen, hydrogen, carbon dioxide, butane and propane, the risks of carbon monoxide poisoning, and the ignition of flammable gases.
- Students shall have knowledge about magnetism, electricity, light, and sound, including practical significance for everyday life; be acquainted with the solar system and galaxies and know about different theories for the development of

the universe; have measured time, distance, speed, mass, volume, and density, and learned about the SI system (International System of Units); and used experiments and a particle model to describe the principal properties of gases, liquids, solids, and phase changes.

As stated previously, the important changes in the new curriculum (Ko6) make it shorter and less detailed than L97. It sets objectives for competencies, but there are no regulations for instructional methods. Five types of basic skills have been introduced: oral skills, writing skills, reading skills, digital skills, and numeracy, which should be applied and developed in every subject at every level.

In Ko6, the subject is called “natural science”. The curriculum¹³ is organized into the following six main areas for grades 1–10: the budding researcher, diversity in nature, body and health, the universe, phenomena and substances/elements, and technology and design.

The most remarkable changes from L97 are the following.

- The process of scientific work has gained explicit attention through the main area called “the budding researcher”.
- Technology and design has become part of the science curriculum. This also draws on mathematics and on arts and crafts.
- Sustainable development has gained more emphasis, as well as the universe.

Moreover, under the new curriculum, a little more instructional time is given to science than before in the lower levels (child stage). Also, while L97 had specific objectives formulated for each grade, Ko6 only has objectives for each stage (grades 1–2, 3–4, 5–7, and 8–10). This, among other things, gives more organizational and pedagogical freedom to schools.

Instruction for Mathematics and Science in Primary and Lower Secondary Grades

Instructional Time

In Norway, instructional time is not set for each grade separately, but only as a total sum for a sequence of grades at the primary and lower secondary levels, respectively. As stated above, instructional time was increased at the primary level in connection with the change in curriculum. Instructional time is given in hours (60 minutes) below.

- *Instructional time in mathematics before mid-2006 (i.e., under L97):* primary school, (grades 1–7), 727 hours and lower secondary school, (grades 8–10), 313 hours
- *Instructional time in mathematics after mid-2006 (i.e., under Ko6):* primary school, (grades 1–7), 812 hours and lower secondary school, (grades 8–10), 313 hours
- *Instructional time in science before mid-2006 (i.e., under L97):* primary school, (grades 1–7), 299 hours and lower secondary school, (grades 8–10), 256 hours
- *Instructional time in science after mid-2006 (i.e., under Ko6):* primary school, (grades 1–7), 328 hours and lower secondary school (grades 8–10), 256 hours.

Instructional Materials, Equipment, and Laboratories

Textbooks or teaching materials are not mandated, recommended, or approved. There are some recommendations on science laboratory equipment and security regulations for science laboratories.

Grade at Which Specialist Teachers for Mathematics and Science Are Introduced

Almost all students have general teachers only throughout the primary level. At the lower secondary level, they may have either general teachers or specialist mathematics and science teachers. At the upper secondary level, they have only specialist teachers (see the section on teacher education below).

Use of Technology

The new curriculum, Ko6, introduced the concept of basic skills, including being able to use digital tools. Therefore, every teacher in each subject and in each grade is supposed to apply digital tools and improve students' skills with them. What to use and how to use it, however, is largely up to the individual teacher or school to decide.

In mathematics, this may mean using calculators, spreadsheets, and various specialized programs. In science, it may mean using calculators, data logging, simulations, etc. Reports often are written with the help of computers and information is collected from the Internet.

Most students in primary and lower secondary school use calculators in their daily work with mathematics. The type of calculator is a local choice. Calculators are allowed in a part of the final examinations. Moreover, computers are increasingly being used in schools. In some schools, students are equipped with portable computers.

Teachers and Teacher Education*Education and Training for Fourth and Eighth Grade Mathematics and Science Teachers*

There are two basic types of teacher education in Norway. At university colleges, there is general teacher education, and at universities, there is subject teacher education. The present curriculum regulations for teacher education were given by the Ministry of Education and Research in 2003.¹⁴

Teacher education at the colleges is for the basic school (grades 1–10). Students with a general teaching certificate are qualified to teach all subjects in all 10 grades.

General teacher education is a 4-year study (240 credit units). The compulsory part, consisting of 120 credit units, is normally covered during the first 2 years. Students choose 60 credit units in subjects taught in basic school and 60 credit units in subjects relevant for school. The compulsory part consists of, among other subjects, 30 credit units of pedagogy, 30 credit units of mathematics, and 20–22 weeks of school practice (practice teaching).

The elective subjects may be extensions of subjects in the compulsory part (such as mathematics) or new subjects with at least 30 credit units containing subject matter didactics as well as school practice. It is up to the teacher education institution to decide which studies are relevant for teaching in basic school. Students can direct their education

toward the lower stages by choosing several subjects or direct it toward the higher stages by choosing fewer subjects, which is a more specialized program.

Central guidelines are given for several subjects, but it is up to the separate colleges to construct the concrete curriculum.

Science, society, and environment is an integrated subject in general teacher education. The subject is not compulsory. However, mathematics, as a compulsory subject, is taught in teacher education at all colleges. Most colleges have supplementary courses in mathematics. The most common programs offer courses with a total of 90 credit units. There are some variations between colleges in regard to the supplementary courses.

Universities offer a different type of teacher education. They educate subject specialists. Normally, a teacher educated at a university will be considered competent to teach two subjects in grades 5–13.

Several years ago, teachers were declared competent by the institutions that educated them. Now, however, it is up to the school's administrators to assess teachers' competencies when they apply for jobs, under the guidelines published by Ministry of Education.¹⁵

Teacher Professional Development in Mathematics, Science, and Technology

The professional development of teachers is the responsibility of the school's administrators (i.e., district or regional authorities). They receive funds for teacher education from the government, but have great freedom to prioritize the types of courses offered. Therefore, there are large variations depending on the school in Norway.

Courses for teachers often are offered by universities or colleges. Several teacher education institutions have ambitious teacher professional development programs.

Examinations and Assessments

National or Regional Examinations

In grade 10, at the end of basic (compulsory) school, students receive an overall achievement grade in each subject, set by the school. Students are selected for one written examination. Approximately one third of them are selected for the mathematics examination, one third for Norwegian, and one third for the English examination. The written examination is set and graded at the national level. Students also may be selected for an oral examination. The oral examination is prepared and graded locally.

Other Tests

There are national tests in mathematics, reading, and English, administered in grades 5 and 8. These tests are constructed on a national basis but graded locally.

Monitoring Individual Student Progress

Teachers regularly write progress reports on all their students. Grades are not given until lower secondary school. Parents are regularly summoned for meetings in school.

Grade Promotion and Retention Policies

There is no longer grade repetition in Norwegian schools.

Suggested Readings

Curriculum documents, as well as most other official documents relating to education, are accessible from the website of Norwegian Directorate for Education and Training (English version): http://www.udir.no/templates/udir/TM_Artikkel.aspx?id=346

More information on the Norwegian education system is accessible from the website of the Ministry of Education and Research: <http://www.regjeringen.no/en/dep/kd.html?id=586>

One useful educational overview by the ministry is given at: http://www.regjeringen.no/upload/KD/Vedlegg/Veiledninger%20og%20brosjyrer/Education_in_Norway_f-4133e.pdf

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Oman

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Richard Siler

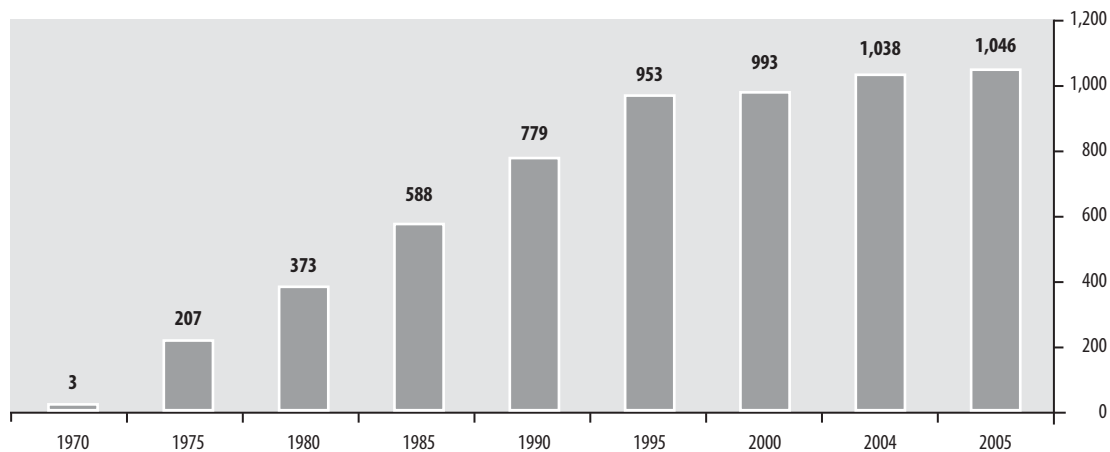
Ministry of Education

Introduction

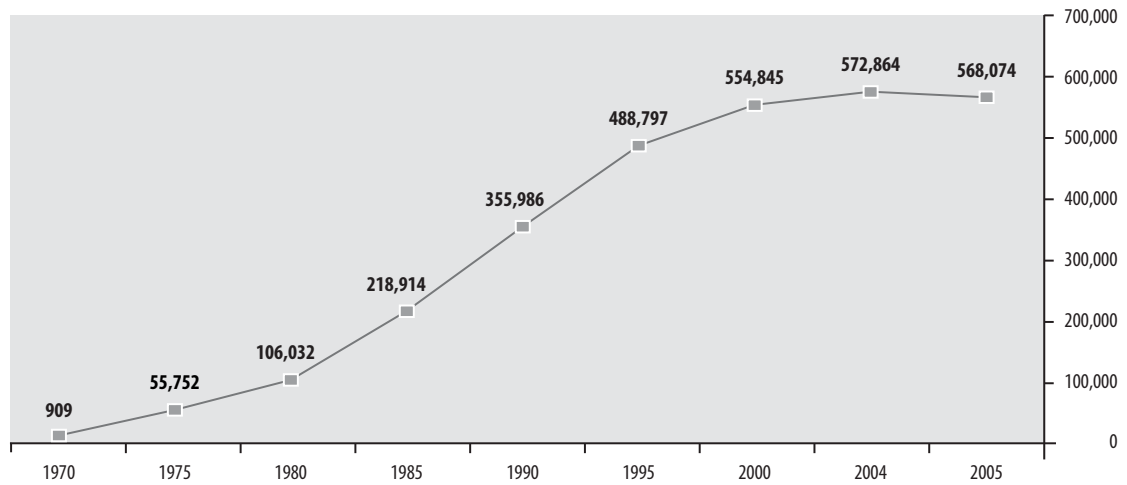
Overview of Education System

Between 1970 and 2006, the education system in Oman was greatly expanded. In 1970, only 909 students were taught by 30 teachers in the country's three schools. By 2005, some 568,074 students were being taught by 37,500 teachers in 1,046 schools. Exhibits 1, 2, and 3 provide a picture of the system's expansion.

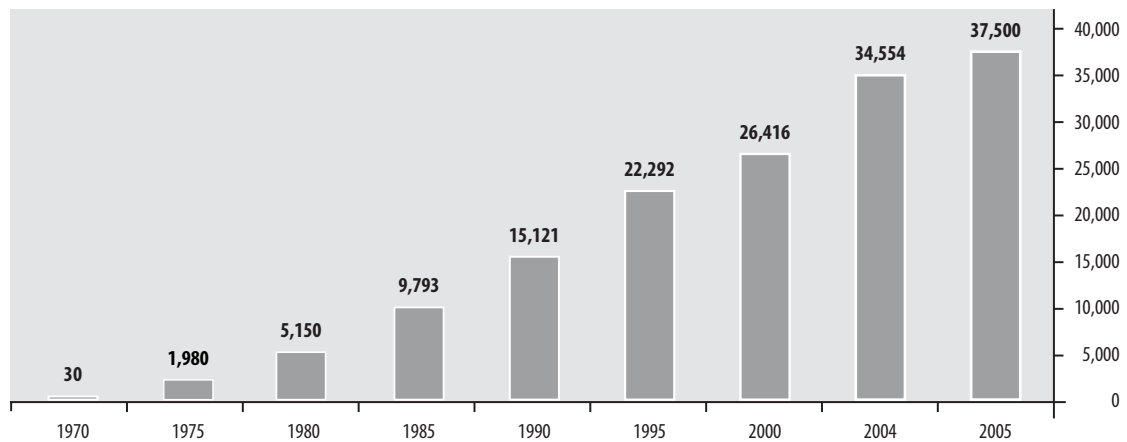
Exhibit 1 Number of Schools in Oman, 1970–2005



SOURCE: Oman Ministry of Education. (2005–2006). *Educational statistical yearbook*. Muscat: Author.

Exhibit 2 Number of Students in Oman, 1970–2005

SOURCE: Oman Ministry of Education. (2005–2006). *Educational statistical yearbook*. Muscat: Author.

Exhibit 3 Number of Teachers in Oman, 1970–2005

SOURCE: Oman Ministry of Education. (2005–2006). *Educational statistical yearbook*. Muscat: Author.

In the early years, the Sultanate's education service was heavily dependent on teachers from neighboring Arab countries such as Egypt, Jordan, and Tunisia. In addition, Britain and countries from the Indian subcontinent provided English language teachers. Training programs for both male and female Omani teachers began in 1976. Since then, there has been an effort, known as "Omanization," to have individuals from Oman hold positions within the Ministry of Education including teachers and educational administrators. The rate of Omanization of teachers more than doubled in the decade between 1990 and 2000. The rate of Omanization of supervisors also doubled in the same decade and more than doubled again in the 3-year period between 2000 and 2003. Today, only about 20 percent of teaching positions are held by expatriates, and administrative positions have been almost completely Omanized (see Exhibit 4).

Exhibit 4 Omanization of Ministry of Education Staff, 1980–2005

Year	Teachers			Administrators			Supervisors		
	Total	Omani	Omanization (%)	Total	Omani	Omanization (%)	Total	Omani	Omanization (%)
1980	5,150	423	8.2	696	183	26.3	170	26	15.3
1990	15,121	4,361	28.8	1,080	703	65.1	316	64	20.3
2000	26,416	17,743	67.2	2,472	2,299	93.0	648	266	41.0
2003	32,345	26,026	80.5	3,273	3,214	98.2	850	709	83.4
2004	34,554	28,214	81.6	3,736	3,684	98.6	933	798	85.5
2005	37,500	30,668	81.8	4,114	4,075	99.1	972	855	88.0

SOURCE: Oman Ministry of Education. (2005–2006). *Educational statistical yearbook*. Muscat: Author.

Oman's education system is historically highly centralized, giving the Ministry of Education the authority to make the majority of decisions facing the country's schools. Currently, however, the Ministry of Education is attempting to implement some decentralization to the 11 regional offices of education, with most administrative functions being handled by personnel in the regions.

Oman has a national curriculum based on learner outcomes established by the Curriculum General Directorate.¹ Learning outcomes for each subject are determined through a system of committees. Each committee is comprised of consultants, experts, curriculum officers, and experienced teachers. Curriculum officers within each subject area prepare student and teacher resources for distribution to students in Oman, so that all students use a common set of resources to study and achieve learner outcomes.

Beginning in 1998, the Ministry of Education began a reform project to convert the existing general education system, which emphasizes teacher-centered, passive learning, and high-stakes examinations, into a student-centered, active-learning pedagogy with an emphasis on continuous assessment. The restructured system is referred to as “basic education”. Activity-based learning is central to basic education. Resources for hands-on activities are incorporated into the mathematics and science curriculum to provide for active-learning classrooms. Exhibit 5 shows the structure of the general education system. Exhibit 6 shows the structure of basic education.

Exhibit 5 Structure of General Education

Level	Grades	Comments
Elementary	1 to 6	Segregated by gender 1,350 minutes per week 160 days per year
Preparatory	7 to 9	Segregated by gender 1,350 minutes per week 160 days per year
Secondary	10 to 12	Segregated by gender 1,575 minutes per week 160 days per year

SOURCE: Oman Ministry of Education. (1999). *Science and Mathematics Framework*. Muscat: Author.

Exhibit 6 Structure of Basic Education

Level	Grades	Comments
Cycle One	1 to 4	Co-educational 1,600 minutes per week 180 days per year
Cycle Two	5 to 10	Segregated by gender 1,600 minutes per week 180 days per year

SOURCE: Oman Ministry of Education. (1999). *Science and Mathematics Framework*. Muscat: Author.

The conversion to basic education is more than 50 percent completed. However, both systems of education continue to operate in the country. The popularity of the basic education pedagogy has resulted in many general education schools adopting basic education resources and teaching techniques. Additionally, the ministry planned a reorganized program for grades 11 and 12 called post basic education. This program offers a choice of pathways and was in place in time for the first cohort of students who completed their 10 years of basic education in June 2007.

The Ministry of Education also has the responsibility of approving the curriculum of all private schools in Oman. The source of the curriculum and learning resources varies among the different schools. Each curriculum must be submitted to the ministry for approval, and students are required to participate in standardized testing when requested to do so.

The ministry has embarked on an ambitious reform involving significant facility development, resource procurement, teaching force development, and curriculum change. This has been and will continue to be a challenge to the education system as it is a costly and disruptive process. The growth of the system, in terms of the increase in the number of students, teachers, and schools, further exacerbates the stress within the system.

There also is a strong desire to increase the use of computer technology in the schools, both as part of a computer literacy program and as a productivity tool to be used in other subjects. This is an expensive undertaking as well. With a relatively young teaching force, few teachers within the system have the background or experience to provide stability within the schools. The need for teacher professional development is significant, but again, is costly and time consuming.

Language and Population

The official language of Oman is Arabic. With the exception of a few private schools that use English, the language of instruction is Arabic as well. Various languages of instruction are used in international schools. However, these schools operate outside the Ministry of Education and follow the educational program of their particular country (e.g., India, Sri Lanka, and the United States).

Emphasis on Mathematics and Science

One of the significant changes in the switch to basic education was the increase in time spent teaching mathematics and science as well as computer technology skills. The ministry is currently establishing standardized assessment tools for mathematics and science for grades 7, 8, and 9.

The Mathematics Curriculum in Primary and Lower Secondary Grades

Summary of National Curriculum Guides for Mathematics Through Eighth Grade

The mathematics curriculum has been developed around a set of five strands: number and number theory; numbers operations; geometry, trigonometry, and spatial sense; measurement; and pre-algebra and algebra. All learning outcomes are correlated to a specific level of achievement in the strand for each grade level.²

Number and number theory. In this strand, the emphasis is on students developing number sense. The curriculum advocates that this is best accomplished by students searching for and understanding the many patterns and relationships among numbers. Being able to use estimation and mental calculation strategies is paramount. It is critical that students have an understanding of the concepts of whole and rational numbers. Integers, negative rational numbers, and irrational numbers are introduced in later grades. Calculator skills also are included. The calculator is considered a tool for studying number patterns, solving realistic problems, and eliminating tedious computations. The curriculum is designed to reflect appropriate calculator use.

Numbers operations. The ability to perform mathematical operations with confidence is parallel to the development of number sense. The four operations of addition, subtraction, multiplication, and division are sequentially introduced throughout the different grade levels for each of the number systems. Specific operations are taught in an iterative manner reinforcing concepts developed in previous grades.

Geometry, trigonometry, and spatial sense. The development of geometrical concepts and the cultivation of spatial awareness are best accomplished through the continuous integration of geometry in the curriculum. Students learn these concepts by actively manipulating, drawing, constructing, and creating geometric shapes and objects and making connections to the real world. Geometry should be experiential and reflected in the students' environment as an exciting and applicable ingredient of mathematics.

Measurement. Emphasis is on the development of measurement sense when students are actively engaged in the processes of comparing, estimating, and measuring. Regular integration with other school subjects such as science, physical education, art, and social studies makes this strand one in which applicability can be easily demonstrated.

Pre-algebra and algebra. Patterns and models are everywhere in our world. They are the links students need to make connections between mathematics and the world in which they live. Exploring patterns and models leads students to develop mathematical competence and gain an appreciation for the beauty and power of mathematics. It is essential for students in the early grades to explore patterns in order to develop an understanding of the concept of a variable and of algebraic thinking. Algebra extends

the study of operations and relationships of numbers to the use of variables. It provides the ability to represent mathematical rules using symbols. Given suitable instruction, students in grades 5 to 10 can learn some of the fundamental aspects of algebra. They should also understand the notion of a function as a rule or mapping that assigns to each member of one set a member of another set. Whenever possible, the practical applications of functions and graphs should be studied, especially as they relate to science. The emphasis is on developing an understanding of basic concepts rather than on the manipulation of symbols or the extensive use of terminology.

The Science Curriculum in Primary and Lower Secondary Grades

Summary of National Curriculum Guides for Science Through Eighth Grade

In general science, the learner outcomes are designed to support the student's acquisition of the knowledge, skills, and attitudes needed for developing scientific literacy.^{3,4}

Knowledge means that students construct knowledge and understanding of concepts in life science; physical science; Earth and space science; the nature of science; and science, technology, and society. Students apply these understandings to interpret, integrate, and extend their knowledge.

Skills means that students develop the skills required for scientific and technological inquiry, solving problems, communicating scientific ideas and results, working collaboratively, and making informed decisions. Four broad areas of skills are outlined in the framework: planning and initiating, exploring and recording, analyzing and interpreting, and communication and teamwork. From grades 1 to 10, each group of skills is developed with increasing scope and complexity of application.

Attitudes means that students develop generalized behavior when the desired attitudes are modeled and reinforced by teachers. Attitudes are not acquired in the same way as skills and knowledge. They cannot be observed at any particular moment but are evidenced by regular, unprompted manifestations over time. Therefore, outcomes for attitudes have been identified, but learning objectives have not.

Instruction for Mathematics and Science in Primary and Lower Secondary Grades

Instructional Time

Each class is 40 minutes long. The school year is 36 weeks, with approximately 32 weeks of instructional time. Exhibit 7 is a summary of the number of hours per week devoted to each subject area by grade for basic education, including mathematics and science instruction. This exhibit also shows time spent in second-language instruction.

Exhibit 7 Classes per Week for Basic Education

Subject	Grade							
	1	2	3	4	5	6	7	8
Islamic	6	6	6	5	5	5	4	4
Arabic	12	12	10	7	7	7	7	7
English	5	5	5	5	5	5	5	5
Math	7	7	7	7	7	7	7	7
Science	3	3	3	5	5	5	7	7
Social Studies	0	0	2	3	4	4	4	4
Life Skills	1	1	1	1	1	1	1	1
Information Technology	1	1	1	2	2	2	2	2
Physical Education	2	2	2	2	2	2	1	1
Art	2	2	2	2	1	1	1	1
Music	1	1	1	1	1	1	1	1
Total	40	40	40	40	40	40	40	40

SOURCE: Oman Ministry of Education. (2006, August). *Planning department directive*. Muscat: Author.

Instructional Materials, Equipment, and Laboratories

All instructional materials and resources are provided to schools through a central warehouse system. Student texts, workbooks, and lab manuals are written, produced, and distributed free of charge by the Ministry of Education. Multimedia resources are provided to the Learning Resource Center of each school. Schools in cycle one (grades 1–4) have manipulative material and equipment in the classroom. All schools in cycle two (grades 5–10) have laboratories.

Grade at Which Specialist Teachers for Mathematics and Science Are Introduced

In cycle one, students receive instruction from teachers specifically trained in combined mathematics and science instruction. In cycle two, students receive instruction from teachers specializing in the specific subject he or she is teaching.

Use of Technology

All basic education schools have a computer lab as well as computers in the Learning Resource Center.

Homework Policies

In cycle one schools, homework is not assigned, but students often voluntarily do revision and practice exercises. There is no portion of their grade directly related to homework.

In cycle two, homework often is used at the teacher's discretion with students being expected to carry on practice and revision exercises as well some individual project work or preparation of reports and presentations. However, like cycle one, there is no portion of the students' grade directly related to the completion of homework.

The Ministry of Education does not have a formal homework policy, but directives from the ministry suggest to schools and teachers that homework should not be used to determine grades.

Teachers and Teacher Education

Education and Training for Fourth and Eighth Grade Mathematics and Science Teachers

Teachers are trained to work in either cycle one or cycle two. The training for cycle one is for female teachers only since all cycle one teachers are female. The training emphasizes pedagogy, with about 30 percent of the coursework devoted to specialization in English, sciences, or humanities. Cycle two teachers have a greater emphasis on specialization, with about 50 percent of their coursework devoted to specialization in English, sciences, or humanities. In order to teach mathematics and science, teachers much have a Bachelor of Education, with a specialization in mathematics and science.

Teacher training in Oman was previously done at Sultan Qaboos University and six teacher colleges around the country. Beginning in 2006, five of the teacher colleges were converted to technical colleges with teacher training downsized to include one college and Sultan Qaboos University. All teacher programs are now 4- or 5-year degree programs. There are now four private universities offering education programs. The first students attending these universities will graduate in 2011.

Examinations and Assessments

National or Regional Examinations

Assessment of learning outcomes is continuous at all grades through examinations that increase in weight at the higher grades. In cycle one, assessment is 100 percent classroom based. Teachers use various assessment tools and techniques provided through ministry documents and teacher guides. In grades 5 to 8, students are assessed using school-developed tests for 30 percent of their grade and continuous classroom assessment for 70 percent of their grade.⁵ Most examinations are developed at the school and regional level, with national testing occurring only at grade 12. Nationally standardized testing is being developed for grades 7 to 9.

Monitoring Individual Student Progress

In cycle one, students receive four report cards each year with letter grades (A to E) for each subject. In grades 5 to 8, students receive two report cards each year with the same letter grades for each subject.

Grade Promotion and Retention Policies

In cycle one, there is no grade retention other than in exceptional cases. Students who receive a failing grade (E) continue to the next grade with planned remedial help and an individual progress plan. In grades 5 to 8, a student failing one subject continues to the next grade. However, students failing more than one subject may be retained. An Attainment Follow-Up Committee within the school is responsible for determining whether retention is in the best interests of the student, the class, and the school.

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Palestinian National Authority

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Introduction

Overview of Education System

Palestinians took over responsibility for their education system in 1994 after the Oslo Accords. At that time, the system of education, the curriculum, teacher qualifications, and school facilities were in need of reform and updating.¹

The Palestinian National Authority operates a centralized education system in regard to its curriculum, textbooks, instructions, and regulations. The administrative structure of the general education system is composed of 22 field directorates (districts offices) of education, including 16 in the West Bank and 6 in Gaza.

Education directorates supervise the administrative and academic performance of schools, with full authority to address issues related to these areas. The Ministry of Education and Higher Education is responsible for recruiting and training teachers and is the liaison on training issues with the education directorates.

The education system in the Palestinian National Authority is composed of four stages: preschool, basic education, secondary education, and university education.

- **Preschool.** This consists of 1 to 2 years of schooling (ages 4–5), monitored by the ministry through supervisors in the field. Although most kindergarten schools are run by the private sector, the ministry provides technical and educational supervision, teacher training and licensing, and some funding.
- **Basic education.** This stage is compulsory for all children and consists of 10 years of schooling, grades 1 to 10, for ages 6–16.
- **Secondary education.** This consists of 2 years of schooling, grades 11 and 12, for ages 17–18. This stage is divided into academic, technical, and vocational domains. The academic domain includes literary (humanities) and scientific streams, while the technical and vocational domains consist of subjects in these domains. Students can elect to enter any one of these domains, but their right to entry is based on successful completion of grade 10 and results of their assessments.

- University education.** The university stage consists of 4 years of a college education to obtain a bachelor’s degree and an additional 2 years for a master’s degree. Some colleges provide 2 years of education that lead to a diploma.

The Palestinian National Authority has three types of schools, demarcated according to gender: boys’ schools, girls’ schools, and co-educational schools, representing 37 percent, 35 percent, and 29 percent, respectively.²

The total number of schools in Palestine is 2,415 with 33,225 classes and 52,465 teachers (nearly all school staff are considered to be teachers) serving 1,104,208 students.³ In the 2007–2008 school year, of the cohort of students who were of the age to attend basic school education (grades 1–10), 86.9 percent were enrolled. At the secondary level, 80.4 percent of the cohort was enrolled. During this same school year, the student-teacher ratio across the education system was about 24:1.⁴

Public (government-run) schools accommodate 70 percent of Palestinian students. Privately run schools accommodate 7 percent of students, while the United Nation Relief and Work Agency schools, which serve children in refugee camps, account for 23 percent of students.

Funding for the education system comes from the government budget through the Ministry of Finance. Just under 18 percent of the total government budget is allocated to education (see Exhibit 1), with the remaining funding coming from donors and international organizations. There are no special governmental funds allocated for mathematics and science learning and teaching, but some nongovernmental donors specify that the money they give be spent on special teaching and learning programs, including mathematics and science. TIMSS provides one such example, since Palestine’s participation in this study is funded by the United Nations Development Programme.

Exhibit 1 Summary Data on Expenditure on Education: Major Economic Indicators Related to Education in the West Bank and Gaza Strip

Indicator	Percentage in 2003
Government expenditure on education as a percentage of total expenditure on education	33.9%
Government expenditure on education as a percentage of total government expenditure	17.8%
Education expenditure as a percentage of gross national income	10.7%
Contribution of education to GDP	8.2%
Education expenditure as a percentage of final consumption	8.9%

SOURCE: The Palestinian Central Bureau of Statistics. (2003). *National accounts*.

In 2000, the implementation phase of the national curriculum began by implementing national textbooks in all subjects. Specialized committees within the ministry had written guidelines for each subject, while national teams of writers used the guidelines to write student textbooks and teacher guides for all subjects and school grades. The textbooks were first implemented in first and sixth grades, followed by textbooks for the second and seventh grades in 2001. By the beginning of the 2006–2007 school year, all students

in all grades were using the Palestinian national textbooks. After long years of using curriculum from other nations, a unified curriculum was applied in both the West Bank and the Gaza Strip.

Language and Population

The languages spoken in the Palestinian National Authority are Arabic, English (which is widely understood), and Hebrew (spoken by some Palestinians). The languages of instruction are Arabic and English.

In 2006, there were approximately 2,444,478 people living in the West Bank, with 42.4 percent in the 0–14 age group, and 1,443,814 in the Gaza Strip, with 47.6 percent who were 0–14 years old.⁵

The Mathematics Curriculum in Primary and Lower Secondary Grades

Summary of National Curriculum Guides for Mathematics Through Eighth Grade

The overall goals of teaching mathematics in **grades 1–8** are to enable children to acquire basic mathematical knowledge and skills to help them do the following.

- Understand the decimal numeration system, operations in this system, and properties of operations (a reasonable level of skills in performing these operations is expected)
- Understand basic geometric figures, their properties, and relationships
- Develop logical thinking that is mostly inductive with the ability to approach deductive reasoning through intuitive activities and formulations
- Develop problem-solving abilities
- Use mathematics in science and technology, and, above all, use them in real-life situations
- Acquire a positive attitude towards mathematics
- Acquire skills in using calculators
- Develop number sense and estimation ability.

The following are the intended guidelines for teaching mathematics by learning strand up to the eighth grade.

- *Number and operations*: understand different numbering systems including natural numbers, integers, rational numbers (including fractions, decimals, and percents), and real numbers (including irrationals); use different forms of representations for numbers including the use of the abacus, number lines, and charts.; compare and order numbers; develop strategies for the four basic operations and recognize and use their properties (commutative, associative, distribution, etc.); and use different rounding and estimation techniques.
- *Theory of numbers*: classify numbers into even, odd, prime, and composite; use factors, multiples, and divisibility rules; and learn basic number theory.

- *Geometry and measurement*: build an understanding of units (length, area, volume, mass, and time); recognize and classify different shapes and solids (triangles, quadrilaterals, polygons, circle, boxes, and cones); measure and draw angles; understand and recognize line symmetry, congruence, and similarity; use and apply congruence theorems (on triangles); discover and apply the Pythagorean Theorem; and discover and apply formulas for finding perimeter, surface area, and volume.
- *Statistics and probability*: organize collected data into tables and graphs; represent data using pictographs, bar graphs, and line graphs; describe data by measures of central tendency (mean, media, and mode); develop an understanding of random experiments and events related to experiments; build an understanding of probability and experimental and theoretical probability linked to equally likely outcomes; and apply the laws of probability.
- *Algebra*: use symbols for variables; recognize open sentences, equations, and inequalities; solve first-degree equations and inequalities with one unknown; factor polynomials; and solve real-world problems.

In eighth grade, students learn trigonometry, including the three basic trigonometric ratios (sine, cosine, and tangent), solve problems using right triangles; use tables to find the trigonometric ratios of acute angles; and apply ratios in real-world contexts (the angle of an elevation and the angle of a depression).

The Science Curriculum in Primary and Lower Secondary Grades

Summary of National Curriculum Guides for Science Through Eighth Grade

The Palestinian education system introduces science for grades 1–10 as a general science. In grades 11 and 12, students entering the scientific stream learn the separate branches of science, specifically physics, chemistry, and biology. Students entering the literary (humanities) stream have the option of continuing to study general science. The majority of science concepts are introduced through an activity-based approach. Thus, students at the lower grades carry out simple activities in class, while students in grade 5 and higher work in science laboratories.

In addition to the traditional science subject, the new Palestinian curriculum plan introduced two other science-related subjects.

- **Technology and applied sciences.** The goal of this subject is to reinforce students' practical skills. A particular emphasis is to make students aware of technology-related issues in their lives, such as the impact of technology on transportation and pollution, the effective use of computers, an appreciation of hands-on technical skills, and an appreciation of how technical knowledge and skills can impact their selection of future careers.
- **Hygiene and environmental sciences.** This subject is an elective for students in grades 7–10. The main goal is to help students understand the concepts and learn skills relating to a wide variety of topics and global issues, such as the importance of water to life, first aid, human interaction with the environment,

diseases, car safety, food and nutrition, religion and environment, family and community health, biodiversity in the Palestinian National Authority, water shortage and conservation, development and civilization, and community and environmental laws.

The goal of the science curriculum in secondary education is to teach students the following topics.

- Human anatomy (body and organs)
- Nutrition and hygiene
- Plants and animals, classifications, and their environment
- Technology in our life
- Light and vision, seasons and climate, and sound and hearing
- Some common types of diseases
- Electricity and simple circuits
- Magnets (types and characteristics)
- Motion (displacement, speed, and velocity)
- Energy (types and transformation, use, and simple calculations)
- Matter and materials (matter states, state change, and transformation)
- Atom composition (elements, compounds, and solutions)
- Solar system (the planets, including Earth and its Moon)
- Cell theory
- Science nature (scientific thinking, concepts, principles, laws, and the experimental approach)
- Fluids (density, pressure in a liquid, and the atmosphere).

Instruction for Mathematics and Science in Primary and Lower Secondary Grades

Instructional Time

Mathematics instruction is five periods per week in grades 1–10. One period is 45 minutes. Science instruction is three periods per week in grades 1–4. In grades 5–10, science instruction was changed from five periods per week to four periods per week in 2002. Work in mathematics and science textbooks comprises about 30 percent of the course time. The instructional time for technology and applied sciences is two periods a week in grades 5–10.⁶

Instructional Materials, Equipment, and Laboratories

The following is a summary of the textbooks, teacher guidebooks, and remedial worksheets used in the schools. Work on mathematics and science textbooks comprises

about 30 percent of the course time. Students in grades 1 to 6 also have access to ready-made worksheets, which support the content of the textbooks.

- **Textbooks.** The organization of the mathematics curriculum is reflected in its textbooks, which usually cover eight units of work per grade level. Each unit contains a number of lessons, and each lesson contains one main theme, examples, and exercises. At the end of the unit, there is a cumulative review of various problems and activities.
- **Teacher's guidebook.** To date, teacher's guides have been developed for grades 1, 2, 3, 4, and 6. The guides help teachers extend their knowledge of mathematics content, provide additional exercises, and suggest methods of presentation and assessment.
- **Remedial worksheets.** These sheets have a remedial purpose and are prepared by committees of teachers and supervisors at the ministerial level and distributed to all students in grades 1, 2, 3, 4, 5, and 6. Students usually work on these sheets with the help of their families.

The ministry makes sure that almost all schools offering a science stream are provided with science laboratories. In general, there are 1,048 science laboratories throughout the school system. The majority of these laboratories are equipped with instructional materials, tools, and devices that are recommended in the curriculum guidelines.

Use of Technology

Some schools use technology such as computers for illustrative purposes and simple activities in mathematics and science. However, in general, the extent to which technology overall is used in teaching and learning these subjects appears to be relatively minor at this time. There are 1,059 computer laboratories throughout the school system.

Teachers and Teacher Education

Education and Training for Fourth and Eighth Grade Mathematics and Science Teachers

There is currently no national, comprehensive program to provide teacher education in the Palestinian National Authority. During 2007, UNESCO supported a new national teacher education strategy that will be finalized by the middle of 2008, with cooperation of the ministry, universities, and local interested institutions. The universities and colleges prepare teachers in a variety of ways and approaches. On the whole, teachers are not well-trained. Pre-service training usually takes place in a university setting, which generally provides insufficient opportunities for practical teaching in schools.

Today, all new teachers must possess, at a minimum, a bachelor's degree, although a few are admitted with a teaching diploma. The following points summarize the present status of qualifications and training of teachers of mathematics and science in Palestine.

- Pretraining and certification have not been required until recently.

- There have been no specific educational requirements in place for people wishing to teach mathematics and science.
- Any undergraduate person studying for a bachelor's degree in mathematics or science can be appointed to be a teacher, but he or she must still comply with certain criteria that relate to the nature and quality of the person's academic qualifications, his or her university entrance examination results, and an interview.

Over the last 3 years, several districts have experienced shortages of mathematics and science teachers. In some instances, nonspecialized teachers have been appointed to teach these subjects in these districts.

Teacher Professional Development in Mathematics, Science, and Technology

The Directorate General for Supervision and Qualification is responsible for teacher professional development. The training plan complements the objectives of the ministry's Five-Year-Plan related to improving the quality of education and the development of human resources.⁷ The training plan elaborates three programs of professional development, delivering expertise and good practice rapidly and widely (the cascade model).

- **Obligatory programs.** The goal of these programs is to improve teachers' subject knowledge and their application of that knowledge in the classroom. Teachers focus on the newly articulated subjects of mathematics, science, and technology within the Palestinian curriculum, in addition to assessment and evaluation training.
- **Developing programs.** These programs focus on pedagogical issues and strategies, as well as the use of information and communication technology inside the classroom. They also provide visual aids for teachers as needed.
- **Optional programs and projects.** These offer teachers an opportunity to improve personal skills and abilities and accelerate their students' skills. One example is the Cognitive Acceleration Through Mathematics Education and Cognitive Acceleration Through Science Education project, which has been implemented in grades 6–8 in 250 Palestinian schools.

At a minimum, newly recruited teachers also must participate in an orientation course, in order to ensure that they are prepared to work in the classroom. They also must attend a course on assessment and evaluation.

According to TIMSS 2003 findings, 78 percent of students who took part in the study had teachers with a bachelor's degree, 15 percent had teachers with a 2-year diploma obtained after the teacher had completed secondary school and took the General Certificate Examination, and 7 percent had teachers with a second degree (master's) or higher.⁸ The last available data about teacher's qualifications indicate that 0.9 percent of Palestinian teachers have a matriculation (*Tawhihi*) certificate or less, while 27.2 percent have a 2-year postsecondary diploma, 60.7 percent have a first university degree, 7.9 percent have a bachelor's degree and a postgraduate diploma, 0.5 percent have a high school diploma, and 2.8% have a master's degree or higher.⁹

The ministry, in collaboration with the British Council, recently established a program designed to evaluate teacher professional development programs offered by the ministry. The purpose of the program is to help the ministry refine its training initiatives.¹⁰

Examinations and Assessments

National or Regional Examinations

The examination system consists of a Certificate of General Secondary Education Examination (*Tawjihee*) for high school students in grade 12 to prepare them for admission to the university. There also is a grade 9 examination, which is offered to students who have not completed grade 9 or have left school and want to achieve a grade 9 competency level equivalent to the Certificate of General Secondary Education Examination.

Within Palestine's own national assessments conducted in 1999, 2000, 2003, and 2005, mathematics was one of the subjects assessed nationally in pivotal grades (4, 6, 8, and 10). However, in 2000, only sixth grade students were assessed in science.

In 1998, the Assessment and Evaluation Center began the first round of national assessments, using standardized national tests along with other questionnaires. The goal of this program of national assessments was to provide policy-makers, curriculum developers, and teacher educators at the ministry with valid and reliable indicators on the effectiveness of the Palestinian education system.

Other Tests

Palestinian students participated in the TIMSS 2003 and 2007 assessments. In both years, students were assessed in grade 8. Palestine's purpose in participating in the study was to obtain achievement indicators that could be used for comparison within the international context and to set baseline data for future comparisons. The ministry also used the findings to inform several reform initiatives, one of which involved the teaching and learning process inside classrooms. In 2000, the ministry also participated in an UNESCO initiative called Education for All, which is a regional assessment of fourth grade students in mathematics, science, and the Arabic language.¹¹

Monitoring Individual Student Progress

Grades 1–3 do not have a grading system (marks), and there are no paper and pencil tests at this level. Rather, teachers assess students on the basis of their progress. Teachers use formative assessments, observations, student portfolios, and other assigned student work as the basis of their judgments.

Grade Promotion and Retention Policies

Students in grades 1–3 progress through each grade with their age cohort. Even if children are not achieving well, the ministry policy is not to hold them back a grade at that level. However, from grades 4–12, ministry regulations allow for 5 percent (maximum) of a class cohort to be held back, with the decision resting on students' total average achievement score for a year. Those students nominated to repeat a year do not receive any remedial teaching during their repeated year.

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Qatar

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Introduction

Overview of Education System

Formal education in the State of Qatar started in 1952. Since then, the comprehensive educational policy has developed on a solid foundation. Guiding the development of this policy has been adherence to the heritage of the Islamic nation and its moderate character, as well as a commitment to the development of educational curriculum and systems that benefit from modern and technological achievements and new educational experiments. Qatar's educational development has accelerated to involve both males and females in every community.¹

Qatar follows a policy of compulsory education until the end of the elementary stage, and free education to all citizens. Basic education consists of an elementary stage (6 years), a preparatory stage (3 years), and a secondary stage (3 years).

The country has 112 government-funded elementary schools (57 for boys and 55 for girls), 58 preparatory schools (28 for boys and 30 for girls), and 44 secondary schools (19 for boys and 25 for girls). Government schools provide free education for the children of non-Qatari residents who work for the public sector. Qatar also has private schools, as well as schools for the different Arab communities (such as Lebanese, Jordanian, Sudanese, and Tunisian schools) and non-Arab communities (such as the Indian, American, and other schools). The State of Qatar supports the establishment of various types of private educational institutions and provides continuous legal and supervisory support.²

The stages of Qatar's education system are presented in Exhibit 1.

Exhibit 1 Education System in Qatar

Level	Name of Stage	Number of Years	Age Group	Remarks
Preuniversity Education	Preprimary	2	4–6	
	Primary	6	6–12	There are separate schools for boys and girls. In boy schools, the teachers are male. In girl schools, the teachers are female. (The same is true for preparatory and secondary schools.)
	Preparatory	3	12–15	This is predominantly general education. There is a preparatory religious school in which a very small percentage (0.5%) of students are enrolled.
	Secondary	General secondary (3 years) Vocational secondary (3 years) Religious secondary (3 years)	3	15–18
University Education		4	18–22	

In 2004, the government released an initiative to develop general education in the State of Qatar under the slogan “Education for a New Era.” This initiative aims to provide the best education for Qataris, preparing them to meet the needs of economic and social development. The main decision-maker in this initiative is the Supreme Education Council. As a result of this reform, most of the Ministry of Education schools are being turned into independent schools. Decisions on which schools should become independent are made jointly by the education authorities in both the Ministry of Education and the Supreme Education Council since the Secretary General of the Supreme Education Council is the Minister of Education.

Schools belonging to the Supreme Education Council are granted more freedom in choosing the teaching techniques and methods in applying the national standards compared to schools belonging to the Ministry of Education. Although the system of public education is centralized at the national level by having two educational authorities (the Ministry of Education and Supreme Education Council), schools, particularly those run by the Supreme Education Council, have their own school boards that make decisions regarding appropriate educational measures.³

At the Supreme Education Council level and as an important part of the education reform, a set of curriculum standards were developed by the Curriculum Standards Office, which is responsible for establishing rigorous curriculum standards in Arabic, English, mathematics, and science. The curriculum standards were developed in these four primary areas because they are deemed to be essential for Qatari citizens to know

in the modern world. Arabic, English, mathematics, and science are referred to as “core subjects” because students’ progress in other subjects often depends on their progress in these four areas.

At the Ministry of Education level, the decision about what should be taught and the objectives to be included in textbooks is made by the curricular unit of the Arab Beroué of Education for the Gulf States (ABEGS), which relies heavily on curriculum experts and designers who have past teaching experience. It also relies on external expertise in designing a curriculum consistent with the culture of each state. These experts may amend about 15 percent of the curriculum.

In order to support and guide the implementation of the “Education for a New Era” initiative, Qatar has developed a state-of-the-art education management information system called the Qatar National Educational Data System. This system includes an assessment component, the Qatar Comprehensive Educational Assessment program, and a set of surveys of key educational stakeholders, the Qatar Comprehensive Survey System.

The decision for Qatar to participate in international studies, such as TIMSS, PISA, and PIRLS, was made largely because international comparative studies about the knowledge and skill levels acquired by students enhance the capacity of policy analysts, decision-makers, educators, and the general public to track the progress of the reform. It is expected that past achievements in these studies will help build a culture of assessment so that constituencies regard assessment as a tool of educational reform and change.

International assessment data have the power to transform education systems. Realizing this potential depends upon creating a range of information products and services that address several purposes, from communicating insights derived from education policy analysis to decision-makers, the media, and parents to targeting curriculum-specific portfolios within designated categories of educators. The question that all stakeholder groups continually ask is how the quality of schooling and the standards of student achievement in Qatar compare to other countries. The educational authorities are determined to take the reform a step forward and underscore the fact that these international surveys are the true indicators of where the education system in Qatar stands.

The establishment of a solid assessment mentality is one of the goals of the educational reform that is underway. However, the road to such a goal seems to be long and will necessitate more support from all the stakeholders. With time, accountability and transparency will be adopted as the basic tenets of an effective educational reform.

Language and Population

According to the last census conducted by the Planning Council in 2004, the total population of Qatar was 744,029.⁴ In addition to Arabic, which is the official language in Qatar, the mosaic population structure has forced the introduction and use of a lingua franca, which in Qatar is English. Among Qataris and expatriates, bilingualism and code switching between Arabic and English are commonplace.

Second-language Instruction

In the Ministry of Education schools, the language of instruction for mathematics and science is Arabic. Apart from some transliterated concepts, the usage of English in mathematics and science lessons is rare. Students enrolled in independent schools, however, receive instruction in mathematics and science in English. The rationale behind teaching in English is that it helps open up a wider range of possibilities for better job prospects and opportunities, and it makes the task of students who wish to continue their studies abroad easier.

Overarching Policies Related to Education and the Curriculum for Mathematics and Science

Since participating in TIMSS, the Ministry of Education and the Supreme Education Council have given increased attention to teaching mathematics and science. Now, both educational bodies are providing professional development for mathematics and science teachers to enhance their teaching capabilities and strategies and facilitate their use of technology resources. An effort is being made now in the Ministry of Education to develop the curriculum for mathematics and for science that underscores the importance of critical thinking and problem-solving skills. Different committees assigned by the Ministry of Education are developing the new curriculum to facilitate the instruction and assessment of students' learning outcomes according to the standards.

The Mathematics Curriculum in Primary and Lower Secondary Grades

Summary of National Curriculum Guides for Mathematics Through Eighth Grade

By the end of **grade 8**, students should have been taught each of the following topics or skills.

- *Number*: whole numbers including place value, factorization, and the four operations; computations, estimations, or approximations involving whole numbers; common fractions including equivalent fractions and the ordering of fractions; decimals including place value, ordering, and converting to common fractions (and vice versa); representing decimals and fractions using words, numbers, or models (including number lines); computations with fractions; computations with decimals; representing, comparing, ordering, and computing ratios (equivalence and division of a quantity by a given ratio); and conversion of percents to fractions or decimals (and vice versa).
- *Algebra*: numeric, algebraic, and geometric patterns or sequences (extension, missing terms, and generalization of patterns); sums, products, and powers of expressions containing variables; evaluating expressions for a given numeric value; simplifying or comparing algebraic expressions; modeling situations using expressions; evaluating functions and formulas for given values of two variable equations; and equivalent representations of functions as ordered pairs, tables, graphs, words, or equations.
- *Geometry*: angles (acute, right, straight, obtuse, and reflex); relationships for angles at a point, angles on a line, vertically opposite angles, angles associated with a transversal cutting parallel lines, and perpendicularity; properties of

geometric shapes (triangles, quadrilaterals, and other common polygons); construct or draw triangles and rectangles of given dimensions; congruent figures (triangles, quadrilaterals, etc.) and their corresponding measures; similar triangles and their properties; relationships between two- and three-dimensional shapes; the Pythagorean theorem (not proof) to find the length of a side; measurement, drawing, and estimation of the size of angles, the lengths of lines, areas, and volumes; measurement formulas for perimeter, circumference, and the area of circles, surface areas, and volumes; measures of irregular or compound areas (e.g., by covering with grids or dissecting and rearranging pieces); the Cartesian plane (ordered pairs, equations, intercepts, intersections, and gradients); line and rotational symmetry for two-dimensional shapes; and translation, reflection, and rotation.

- *Data and chance*: reading data from tables, pictographs, bar graphs, pie charts, and line graphs; organizing and displaying data using tables, pictographs, bar graphs, pie charts, and line graphs; and characteristics of datasets including the mean, median, and range.⁵

The Science Curriculum in Primary and Lower Secondary Grades

Summary of National Curriculum Guides for Science Through Eighth Grade

By **grade 8**, students should have been taught each of the following topics or skills: what is around us; plants and animals around us; a tree as a seed; the human body; states of matter; plants in our life; plants in our environment; animals in our environment; the five senses; scientific games; what is in the sky; parts with functions; living organisms' responses; motherhood in the animal kingdom; a good meal and its importance for children's health; a journey to the moon; characteristics of living organisms; life on Earth; matter around us; humans and the universe; food and living organisms; the Earth and its atmosphere; magnetism; the structure of living organisms; sound and light; height; electricity; the environment and its resources; environmental balance and environment variety; the musculoskeletal system; the effect of living things on humans and the environment; electrostatic charge; space (planets and stars); the nervous system; the periodical table and chemical reactions; electric energy; physical phenomena in a human's life; reproduction in living organisms; and human public health.⁶

Instruction for Mathematics and Science in Primary and Lower Secondary Grades

Instructional Time

In grades 1 and 2, mathematics and science are allocated 45 minutes of the total teaching time per week. In grades 3 and 4, students receive three, 40-minute periods of teaching time for mathematics and science per week. In grades 5–8, the instructional time allocated to mathematics and science is four, 40-minute periods per subject per week. In independent schools, lesson periods may last up to 60 minutes, with instructional time determined by the school board.

Instructional Materials, Equipment, and Laboratories

All schools, whether independent or public, have science laboratories and all the necessary equipment to foster better instruction in science. A major difference between the Ministry of Education and independent schools is the teaching materials used by teachers. While it is customary in the Ministry of Education schools to supply teachers with textbooks outlining the course objectives and contents, independent school teachers, through a coordinated effort among support teams, put together a set of learning objectives based on the strands and objectives that form the core of the Qatar national standards. Some schools may opt to use a publishing company, which helps teachers develop a textbook tailored to the key performance standards that the school board deems necessary for students to know.

Grade at Which Specialist Teachers for Mathematics and Science Are Introduced

Students first start to have specialist teachers for mathematics and science in grade 5. Instruction in mathematics and science prior to this grade is offered by nonspecialist teachers. In independent schools, instruction in mathematics and science is provided by specialist teachers.

Use of Technology

One of the major benefits of the educational reform currently taking place in Qatar is the provision that schools provide all Internet technology tools. Qataris take pride in being familiar with these tools.

Homework Policies

In addition to classroom assignments, students are assigned a variety of out-of-school activities that they have to perform at home. These may include, among other things, projects, a unit synopsis, and portfolios.

Teachers and Teacher Education

Education and Training for Fourth and Eighth Grade Mathematics and Science Teachers

At a minimum, all teachers must have a Bachelor of Arts degree in mathematics or science. Once recruited, teachers must go through a series of training programs intended to foster and enhance their teaching capabilities. At the school level, teachers do exchange classroom visits that are usually scheduled by the subject matter supervisor or inspector. A different trend is applied in independent schools. Support teams, usually recruited from outside the country, liaise between teachers of different disciplines and continuously update teachers on the latest teaching methods and techniques. The work of these support teams occurs over the course of a year. Recently, the Supreme Education Council introduced an information network whereby teachers are able to use items and stimuli from the item bank network developed by the Evaluation Institute. Teachers also are able to access the national reports on student performance on the national examination, the Qatar Comprehensive Educational Assessment, and the international studies that Qatar

has successfully fielded (e.g., PISA). This also will be true of TIMSS once the results are disseminated and the national report is finalized.

Teacher Professional Development in Mathematics, Science, and Technology

To improve teachers' assessment techniques, on a yearly basis, the Supreme Education Council holds item writing workshops intended to keep teachers updated on the assessment enterprise and show them how the key performance standards (i.e., assessable standards) should be targeted. Items developed by teachers then are submitted to Educational Testing Service, the testing company in charge of tailoring the Qatar Comprehensive Educational Assessment. Subject matter experts receive a report on teacher performance, which is used to pinpoint the areas of strengths and weaknesses and identify ways of improving teachers' assessment skills.

Examinations and Assessments

National or Regional Examinations

In addition to school-level formative and summative assessments, students sit for the national assessment examination, the Qatar Comprehensive Educational Assessment. This assessment targets the four core subject areas: Arabic, English, mathematics, and science. At the beginning of the reform, students in all schools (both public under Ministry of Education and independent under the Supreme Education Council) took this assessment. Over time, the scope and sphere of coverage was reduced to include only students enrolled in independent schools. The items on the Qatar Comprehensive Educational Assessment are scored electronically via a network developed by Educational Testing Service, and the results are released in December of the following academic year.

The General Certificate Examination is an exit examination taken by students enrolled in grade 12. The Ministry of Education and the Supreme Education Council have two different policies related to this examination. In Supreme Education Council schools, students sit for one exit examination, usually scheduled in May. The goal of this examination is to determine whether students have mastered the strands and objectives of the national standards. Student performance on the exit examination is calculated out of 50 percent. Students' total scores consist of the exit examination score (50%) and student performance during the school year (50%).

In the Ministry of Education schools, students sit for two semester examinations, usually scheduled in January and May. The students' passing scores are the result of their performance on both examinations, with 50 percent allocated to the first examination and 50 percent to the second.

Monitoring Individual Student Progress

At the end of every semester, parents of children enrolled in grades 1 through 11 in ministry schools receive certificates comprising their children's examination scores in every subject. These certificates are intended to help parents follow up on their children's performance,

as well as the degree of knowledge acquired. If, after reviewing the certificates, their children's performance levels are not up to parents' expectations, parents may choose to enroll their children in enrichment lessons.

In independent schools, in addition to the certificates that include students' scores based on the formative and summative assessment policy endorsed by the school, the Supreme Education Council provides parents with reports pertaining to their children's performance on the Qatar Comprehensive Educational Assessment. Following the dissemination of results, parents and class teachers receive reports comprising the students' scores, as compared to the performance level scores set by experts and teachers who participated in a performance level setting workshop. Student performance is categorized into three levels of performance standards: meet standards, approach standards, and below standards.

Grade Promotion and Retention Policies

Grade promotion and retention more or less follow the same norms and rules endorsed by many countries. Specifically, grade retention is not applied at the primary level, and students are made accountable when they reach the preparatory and secondary levels.

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Romania

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Introduction

Overview of Education System

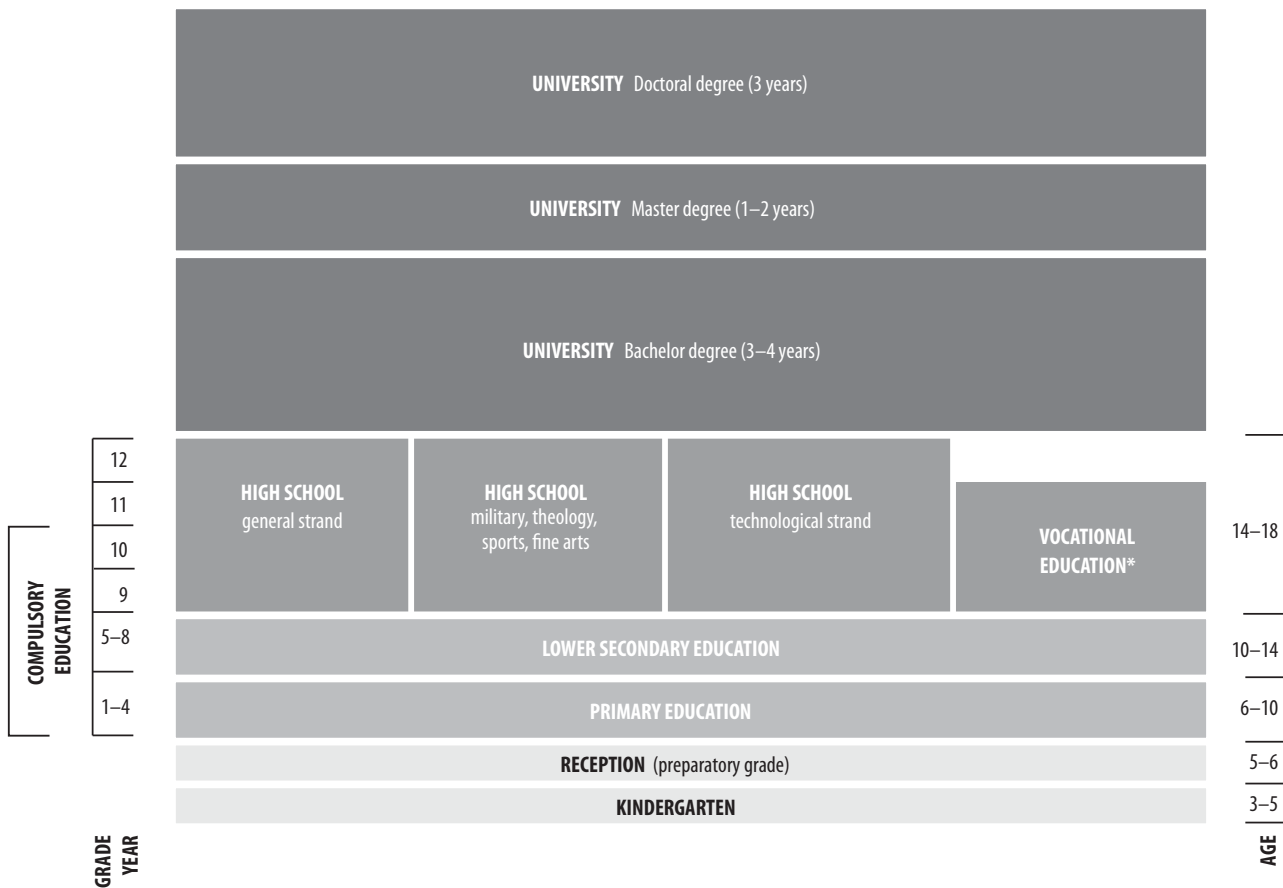
The general management of education at the national level is provided by the Ministry of Education, Research, and Youth as the central authority and is implemented by county inspectorates as regional authorities. The Education Act² regulates the management of education at all levels. According to the law, the ministry coordinates and controls the national education system, organizes the public education network, and suggests the government enrollment figures. Moreover, the ministry approves the curriculum and school textbooks for primary and secondary education, organizes national contests for school textbooks, coordinates the activity of research, and is in charge of preservice teacher training and teacher professional development. Decentralization and new economic and social practices, such as local and institutional autonomy, have been slow to take hold. In 2005, a strategy for decentralization was approved at a governmental level. At this time, a new education law is under public discussion. Exhibit 1 presents the education system in Romania.

The goal of preprimary education is socializing children, as well as providing them with opportunities for learning activities in the curricular areas that later will become the compulsory core curriculum.

According to the law, all Romanian citizens are obliged to receive education for a period of 10 years after preschool education. The obligation to attend school terminates when students are 16 years old or when they have completed lower secondary school, whichever occurs first.

Almost all schools in Romania—preprimary, primary, lower secondary, upper secondary, and university—are state run. There only are a small number of private schools. Private education is considered an alternative or a complement to public education, and the institutions of private education, after being accredited, become part of the national education system.

Exhibit 1 Romanian Education System



* After completion, graduates of vocational education can continue their studies by enrolling in grade 11 of the technological high school strand.

After 1989, the Romanian education system began intense periods of change at the decision-making level. Although it is not easy to distinguish specific stages of the reform and accompanying goals, the reform of education in Romania might be seen in four phases. The first was an exploratory and preparatory phase (1990–1994) followed by a capacity-building and institutional development phase (1995–1997). The period from 1998–2000 represents the third phase, where the reform program accelerated the pace of implementation. After 2001–2002, the reform process slowed as structural changes were implemented without adequately preparing the system. Currently, the education system is affected by contrasts among the formal requirements of a modern orientation; the school, which is becoming more conservative; the students who are integrated into the contemporary dynamic, socioeconomic context; and the teachers who return to old habits when there are too many contradictory regulations.

Language and Population

Romania's official language is Romanian. In the majority of schools, Romanian also is the language of instruction. Nevertheless, in multicultural communities and mainly where a minority group is significant in numbers, the language of instruction, including in mathematics and science, becomes the respective minority language. At the primary level, there are schools where the National Curriculum is taught in one of the following languages: Bulgarian, Czech, German, Hungarian, Serbian, Slovak, and Ukrainian. Some private schools also provide instruction in English.

The languages spoken at home correspond to the various ethnic groups—predominantly Romanian and the various minorities speaking Hungarian, German, Jewish, Gypsy, the Slavic languages, Turkish, Greek, and Armenian.

Second-language Instruction

Minority groups learn mathematics and science in the fourth and eighth grades in two different ways according to the type of school and community. Minority students either can learn mathematics and sciences in Romanian (while their mother tongue is the language of instruction) or study these subjects in their mother tongue.

The Mathematics Curriculum in Primary and Lower Secondary Grades

Summary of National Curriculum Guides for Mathematics through Eighth Grade

According to the curriculum, learning mathematics in compulsory education emphasizes the nature of mathematics as an activity of problem solving based on a body of knowledge and procedures that can be approached by exploration, as well as a dynamic discipline, which is closely related to society by its relevance in everyday life, the natural sciences, technology, and the social sciences. As a whole, the philosophy of the mathematics curriculum, introduced in 1997, proposes a change of focus from theoretical arithmetic to a variety of problem contexts generating arithmetic; from the application of algorithms to using strategies in problem solving; from memorization and repetition to exploration-investigation; from the teacher's role of information transmitter to that of an organizer of various learning activities for all students, depending on their individual level and stage of development; and from the subjectivism and rigidity of the grading system to transforming the assessment as a means for self-evaluation and stimulation.

In Exhibit 2, the curricular standards of achievement are presented, as well as the targets for the end of primary education and the end of eighth grade.

Exhibit 2 The Mathematics Curriculum in Romania: Curricular Standards of Achievement

	Framework Objectives	Curricular Standards of Achievement at the End of Primary Education	Curricular Standards of Achievement for the End of Eighth Grade
1	Knowing and using specific mathematical concepts, terminology, and computing procedures specific to mathematics	<p>S1. Write and read numbers up to 1,000,000</p> <p>S2. Use mathematical terminology correctly</p> <p>S3. Perform addition and subtraction with natural numbers lower than 1,000,000</p> <p>S4. Perform multiplication and division with natural numbers lower than 1,000</p> <p>S5. Use fractions in simple exercises of addition and subtraction with the same denominators</p>	<p>S1. Write, read, and compare real numbers and represent them on the number line</p> <p>S2. Perform operations with real numbers (possibly represented by letters)</p> <p>S3. Use estimations and approximations of numbers and measurements (lengths, angles, surfaces, and volumes)</p> <p>S4. Use elements of logic and set theory, as well as relations, functions, and sequences in solving problems</p> <p>S5. Solve equations and inequalities and perform algebraic calculations using algorithms, specific formulas, and methods</p> <p>S6. Use qualitative and metric properties of geometric 2-D and 3-D shapes in problems involving demonstrations and computations</p> <p>S7. Use the relative positions of geometric shapes and elements of geometric transformations</p> <p>S8. Record, process, and present data using elements of statistics and probabilities</p>
2	Developing capabilities for exploration/ investigation and problem solving	<p>S6. Recognize, represent, and classify 2-D and 3-D shapes</p> <p>S7. Formulate and solve problems that involve performing, at most, three operations</p> <p>S8. Use arithmetic reasoning in problem solving situations</p> <p>S9. Use simple modalities to organize and classify data</p> <p>S10. Recognize and develop patterns for sequences</p> <p>S11. Perform estimations and approximations within practical situations</p> <p>S12. Use nonconventional measure units in various contexts</p> <p>S13. Use conventional measure units for time, mass, length, and volume of objects</p>	<p>S9. Identify a problem and organize solving it efficiently</p> <p>S10. Use various representations and methods to clarify and justify (prove) statements</p> <p>S11. Build generalizations and check their validity</p>
3	Developing the capability to communicate using the mathematical language	<p>S14. Express computing strategies and the results of exercises and problems in a concise and clear manner, verbally and in writing</p>	<p>S12. Understand the overall significance of mathematical information from various sources</p> <p>S13. Express one's own attempts to solve a problem correctly, verbally or in writing</p> <p>S14. Engage in mathematics activities as a member of a group</p>

The Science Curriculum in Primary and Lower Secondary Grades

Summary of National Curriculum Guides for Science through Eighth Grade

Beginning with the 1998–1999 school year, new curricula for teaching science at grades 3 and 4 and for teaching geography at grade 4 were introduced.³ In the same school year, new curricula for biology, physics, chemistry, and geography at the elementary level were introduced. Since 2003, integrated sciences have been part of Romanian primary students' instruction beginning in grade 1.

In Exhibits 3 through 6, the curriculum standards for biology, chemistry, physics, and geography and what students are expected to achieve during compulsory education are detailed.

Exhibit 3 Curricular Standards of Achievement in Biology

Attainment Targets	Standards at the End of Grade 8
1. Knowledge and understanding of biology phenomena, terminology, and principles	S.1. Use biology terminology and concepts correctly to describe and interpret biological processes S.2. Identify, interpret, and classify structural and functional properties of organisms
2. Developing the capacity of exploring/researching and solving biology problems	S.3. Carry out research on the living world by correctly applying the methods studied S.4. Identify a problem and select the adequate methods and means of solving it S.5. Interpret and comment on the data collected while carrying out an experiment and drawing conclusions
3. Developing the capacity of communicating correctly using specific biology language	S.6. Present one's own research activities on the living world, verbally or in writing S.7. Select and use appropriate sources of information

Exhibit 4 Curricular Standards of Achievement in Chemistry

Attainment Targets	Standards at the End of Grade 8
1. Knowledge and understanding of chemistry phenomena, terminology, and concepts	S.1. Classify simple/complex substances, mixtures, and chemical reactions according to one or more criteria S.2. Describe and interpret phenomena, properties, and models
2. Developing the capacity of experimenting and exploring/researching the real world by using instruments and procedures specific to chemistry	S.3. Experiment using known chemical substances S.4. Represent and interpret observations/data resulting from research/experiments, in the form of tables, graphs, and diagrams
3. Developing the capacity of analyzing and solving problems	S.5. Draw conclusions on the basis of the physical and chemical behavior of substances S.6. Apply mathematics relations/expressions of chemistry laws to solving quantitative problems
4. Developing the capacity of communicating using chemistry language	S.7. Use scientific terminology when presenting a piece of research, verbally or in writing

Exhibit 5 Curricular Standards of Achievement in Physics

Attainment Targets	Standards at the End of Grade 8
1. Knowledge and understanding of physics phenomena, terminology, and concepts	S.1. Describe physical phenomena observed, using specific terms S.2. Use measurement equipment and specific methods to determine the physical values studied
2. Developing the capacity of experimenting and exploring the physical world reality, by using instruments and procedures specific to physics	S.3. Carry out experiments, either controlled or not, starting from physical phenomena studied S.4. Organize, use, and interpret data from experiments
3. Developing the capacity of analyzing and solving problems	S.5. Interpret in a qualitative manner the content of a problem from the point of view of physics S.6. Use mathematical relations and principles and laws of physics for solving theoretical or practical problems
4. Developing the capacity of communicating using physics language	S.7. Use specific terms in formulating observations and conclusions drawn from experiments S.8. Understand the overall meaning of physics-related information from various sources

Exhibit 6 Curricular Standards of Achievement in Geography

Attainment Targets	Standards at the End of Grade 8
1. Understanding the position in space and in time	S.1. Correctly define the position of basic elements in space and time S.2. Correctly connect elements in real life with their symbolic representation
2. Knowledge and interpreting drawing and maps	S.3. Use information from maps and drawings to represent a geographic reality
3. Making adequate use of specialized vocabulary	S.4. Write a report on a given topic
4. Researching and interpreting the geographic phenomena	S.5. Write a report on one's own research work related to a geographic phenomenon.

Instruction for Mathematics and Science in Primary and Lower Secondary Grades*Instructional Time*

The new curriculum framework allows schools to design timetable schemes more in line with their instructional goals. Of the instructional time, 80 percent is dedicated to the core curriculum, and 20 percent is school based.⁴ Details of instructional time designated for particular subject areas are shown in Exhibits 7 and 8. In addition, students in compulsory education might choose a supplementary, optional class per week, which is allocated in the curricular areas of mathematics and science. The number of optional classes increases in upper secondary.

Exhibit 7 Number of Weekly Instructional Hours for the Curriculum in Grades 1 to 4

Curricular Area/Subject	Grade 1	Grade 2	Grade 3	Grade 4
Mathematics	3–4	3–4	3–4	3–4
Natural Sciences	–	–	1–2	1–2
Environmental Studies	1	1	–	–
Geography	–	–	–	1–2
Optional subjects	1–3	1–3	1–3	1–3
Minimum number of hours/week	18	18	19	21
Maximum number of hours/week	20	20	22	24

SOURCE: Order of the Minister of Education No. 4686 (May 8, 2003) and Order of the Minister of Education No. 5198 (January 11, 2004).

Exhibit 8 Number of Weekly Instructional Hours for the Curriculum in Grades 5 to 8

Curricular Area/Subject	Grade 5	Grade 6	Grade 7	Grade 8
Mathematics	4	4	4	4
Biology	1–2	2	2	1–2
Physics	–	2	2	2
Chemistry	–	–	2	2
Geography	1–2	1–2	1–2	2
Optional subjects	1–3	1–3	1–2	1–2
Minimum number of hours/week	24	26	29	29
Maximum number of hours/week	26	28	30	30

SOURCE: Order of the Minister of Education No. 4686 (May 8, 2003) and Order of the Minister of Education No. 5198 (January 11, 2004).

Instructional Materials, Equipment, and Laboratories

Since 1995, textbooks have been selected from a list of manuscripts in a national contest, which consists of assessing the content from the perspective of several criteria and bidding on the costs of publishing the textbooks. There is an officially approved (by the ministry) list of textbooks that have won the contest, and teachers are free to choose one among the approved textbooks. The mathematics and sciences textbooks usually are used in class as sources of exercises. Teachers may receive teaching guides, but they are not compulsory. Besides the free textbooks, teachers and students can buy other print materials that are available on the market.

Grade at Which Specialist Teachers for Mathematics and Science Are Introduced

In grades 1–4, one teacher teaches all subjects with some exceptions (foreign languages and religion are taught by specialized teachers). In lower secondary, each subject is taught by a single specialized teacher.

Each teacher is free to develop his or her teaching methods. The curriculum does not impose certain methods but provides examples of learning activities for each reference objective. Practical activities and problem solving are relatively important. There are

objectives that deal with group work activities, but teachers do not regard their use as being compulsory. Advanced classroom management (using a certain type of class organization as it relates to certain objectives) is known and used by a small number of teachers.

Use of Technology

The systematic use of computer software is relatively limited. Although the market presents educational software for teaching mathematics or science, its use is not very popular yet in Romania for a few reasons. First, teachers are not very familiar with computer use and in general, with information and computer technology (ICT) for educational purposes. Also, average schools do not have enough equipment for one-to-one instruction. Finally, the rather traditional trend in the teaching approach does not encourage the spread of modern technologies. However, some national programs are focused on ICT in education, and, as a result, its use is progressing. The use of calculators in school is less popular than the use of computers.

Homework Policies

The tasks given in mathematics and science to prepare at home are compulsory. There is no official regulation regarding this issue. Homework always is written, and the quantity depends on the teacher.

Teachers and Teacher Education

Education and Training for Fourth and Eighth Grade Mathematics and Science Teachers

Until 1999, primary teachers were trained in pedagogical high schools, which provided them with mathematics and science training similar to any other humanistic high school, plus a course in arithmetic and a course in science and one in mathematics teaching and one in science teaching. Since 1999, the initial training of primary teachers is completed in 3-year university colleges. Mathematics and science training in these colleges is similar to the training in pedagogical high schools.

Mathematics teachers for secondary education, as well as physics, chemistry, biology, and geography teachers, previously were trained at the university level for 4–5 years. Since 2005, however, within the Bologna process, university training takes 3 years. In addition, to obtaining a teaching certificate, graduates must enroll for the psycho-pedagogical module.

Teacher Professional Development in Mathematics, Science, and Technology

The Ministry of Education, which coordinates and finances teacher professional development, grants teachers the right to this training. Teacher professional development is provided by higher education institutions through courses in a particular area or in methodological and pedagogical training.

In each county, the inspectorate administers a teaching staff center, which provides documents and additional training activities for teachers. Teachers are offered formal training every year.

Examinations and Assessments

National or Regional Examinations

Starting with the 2007–2008 school year, the first national examination including mathematics took place at the seventh and eighth grades. The role of this examination is to give students access to high schools. It is meant to measure students' capacities in the following subjects: Romanian language and literature, mathematics, and Romanian history/Romanian geography. Students who belong to national minorities study in their mother tongue languages and are administered a supplementary examination in the language and literature of their mother tongue.

The National Baccalaureate Examination is a criterion-based examination that certifies the knowledge and capacities of high school graduates at the end of high school studies. The Romanian language, a foreign language, and the mother tongue⁵ are compulsory subjects for this examination, no matter which tracks were followed. On the basis of a baccalaureate diploma, students can take the entrance examination for higher education.

Periodically, there is an assessment of nationally representative samples for grade 4 students.⁶ Students are tested in three subjects: Romanian language, mathematics, and science. The findings of these national assessments are linked to the assessment techniques that primary school teachers are encouraged to use in the classroom.⁷

Since 2000, the National Assessment and Examination Service⁸ has carried out a major nationwide assessment program called the National Program for the Assessment of Educational Progress. Teams of experts in curriculum and experts in assessment have developed band descriptors, which detail the curricular objectives on three levels. In general, however, teachers are not very familiar with the manner of using these levels.

Other Tests

Assessment approaches typically include tests and traditional exercises (oral and written). Project work and self-assessment are used occasionally. Assessments are based on the objectives for each age level prescribed by the curriculum. Very few standardized reading, mathematics, and science tests, which are based in primary schools, are available for national assessments. Most teachers still use their own experiences and knowledge to monitor students' abilities.

Monitoring Individual Student Progress

In primary education, marks have been replaced by grades—very well, well, sufficient, and insufficient—which correspond to the following levels of performance: high, average, and minimal. Instructions for classroom assessment, both continuous and final, are described in teacher guides for grades 1 to 4. At the end of each semester, a summative assessment is undertaken.

Grade Promotion and Retention Policies

The teacher, taking into account the student's general progress, determines the passage of each student to the next class. There is no examination at the end of primary school.

In lower and upper secondary education, grading from 1 to 10 is used, with 5 being the minimum for graduation from one grade to the next.

Suggested Readings

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References

- 1 The authors are both senior researchers at the Institute for Educational Sciences.
- 2 Act 84 of 1995 was republished with all the subsequent changes and additions.
- 3 Some revisions of the science curriculum for grades 3–4 took place in 2004. The geography curriculum was revised in 2006.
- 4 Schools have a significant role in developing school-based curriculum. They can offer students optional subjects/courses/themes covering 1–3 hours weekly depending on the teacher's decision.
- 5 This is for those students who study in the mother tongue language.
- 6 These tests have an external character and are meant to certify and maintain educational standards.
- 7 The information on evaluation instruments and techniques is drawn from the School-based Assessment and Examination (Litoiu, 2001).
- 8 The National Assessment and Examination Service (NAES) is an autonomous body that has responsibility for evaluating and examining school results.



Russian Federation

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Introduction

Overview of Education System

In the 1990s, Russia's political transition led to significant changes in education, confirmed by the 1992 Law on Education. The Russian education system has become more decentralized in its decision-making and funding. In the 2006–2007 school year, there were 58,503 state-municipal schools with 14,263,657 students and 716 nonstate schools with 71,278 students.¹

On the federal level, the education authorities are responsible for the following.

- Making and implementing federal policy in the field of education
- Developing the legislative basis for the functioning of the education system
- Establishing the federal component of the state educational standards
- Elaborating on the model study plan, as well as recommended programs of study for school subjects, on the basis of state educational standards (federal component)
- Annually approving the federal list of recommended textbooks
- Organizing the federal system of teacher education and teacher professional development.²

The 1992 Law on Education gave much autonomy and responsibility to schools. The educational program, including the curriculum, annual yearly study plan, and timetable of classes at educational institutions, is determined independently by the institution itself on the basis of recommended documents. State and local government authorities do not have the right to change the curriculum or an institution's study schedule once approved, except when stipulated by the Russian legislature.

The main documents regulating school instruction include the educational standards and the program of study. In the former Soviet Union, all schools had unified curricula, which have been replaced by state educational standards, including the minimum

compulsory content to be taught and student achievement requirements at the end of primary, basic, and upper secondary education.

The state educational standards of general education and the curricula for different school subjects (including mathematics and science) are developed cooperatively by subject matter specialists, teachers, and representatives from academies at the federal level. After approval by the Ministry of Education and Science, the standards are recommended for use and serve as the basis for developing textbooks, instructional materials, and assessments and examinations. Presently, there is a transitional period from the national curriculum of 1998 to the national curriculum of 2004, therefore, schools are allowed to use both curricula.

The state system of education includes preprimary, primary, and secondary education, which includes basic or lower secondary and upper secondary education. General education (grades 1–9) is compulsory according to the Constitution of the Russian Federation.

Preprimary education, ages 3–6, is not compulsory. In 2006, preprimary education included 46,200 preprimary educational institutions with 4.71 million children.³ **Primary education** (grades 1–4) may be provided in primary schools, basic schools that include the primary stage, or secondary education institutions that include all three stages. **Secondary education** includes basic or lower secondary education (grades 5–9) and secondary or upper secondary education (grades 10–11).

Different types of schools are organized to provide general education: general schools and schools specializing in specific disciplines. Specialized schools include those with higher educational standards than general schools, such as *gymnasiums* (with broad, mostly humanitarian education) and *lyceums* (preparation for attending a university), evening schools, boarding schools, and schools for children with special needs. Some schools provide in-depth education in some subjects. Many of these schools offer studies in mathematics and physics. In the upper secondary stage, the majority of schools offer different profiles of study (humanitarian, scientific, general, linguistics, technical, etc.) to reflect educational standards.

Since 2000, the Russian government began developing a new educational reform program. The main focus was modernizing the structure and content of general education, raising the standards of a quality education, providing equal access to education, developing effective mechanisms for transmitting social requests to the education system, and broadening public participation in managing education. The structure and content of general education were changed according to the reform goals. For example, elements of probability theory and statistics were introduced in mathematics, and the practical applications of science subjects (physics, chemistry, and biology) were strengthened. For the first time, learning skills were explicitly stated for all stages of general education.⁴

In 2006, a new strategic goal of education in Russia was formulated to provide innovative, long-term development of the country. These new requirements have changed the understanding of human preparedness from fulfilling professional and social roles to innovative behavior, which only may be achieved by forming an innovative system

of education—a system oriented to the new educational results. Although the national curriculum of 2004 is not yet fully implemented, the development of state educational standards has begun, and more emphasis has been placed on key competencies, personal creative development, and interdisciplinary outcomes.

To provide the complex systematic modernization of education at the regional and local levels, the government initiated and provided financial support for different types of competitive national projects directed at regions, institutions, teachers, and students. The winners demonstrated outstanding achievement and innovative approaches and were considered to be disseminators of innovative practice.⁵

Language and Population

Russian is the official language of the Russian Federation. In the majority of schools (more than 95%), the language of instruction for all subjects, including mathematics and science in fourth and eighth grades, is Russian, although some students receive instruction in one of the country's 79 languages of national ethnic groups.

Overarching Policies Related to Education and the Curriculum for Mathematics and Science

The major changes in mathematics and science education were influenced by fundamental social transformations in Russia. Humanitarian, cultural, and pragmatic components of mathematics and science gained a new emphasis, with the general intellectual and cultural development of students being one of the principal objectives for teaching these subjects. The focus is on finding a balance between academic and human or social aspects in teaching mathematics and science and developing new standards for school outcomes.

The Mathematics Curriculum in Primary and Lower Secondary Grades

Summary of National Curriculum Guides for Mathematics Through Eighth Grade

For all three stages of general education, the mathematics national curriculum includes the goals for mathematics education; content to be taught, referred to as compulsory minimum content; and requirements for student achievement (what students should know and be able to do at the end of each stage of general school). The national curriculum for mathematics education, shown below, lists the compulsory minimum content and also includes some topics and concepts that are taught as preparation for future study (although they are not assessed at the end of the stage).

In 1998, the emphasis in mathematics education in **primary education** (grades 1–4) began to be placed on developing general cognitive skills, establishing the correlations between subject-verbal-schematic-symbolic models, developing a mathematics culture, and working with algorithms and schemes. In 2004, the application of knowledge and skills in practical and everyday situations was implemented into the requirements for student achievement, including orientation in the surrounding world, comparison and ordering objects by different characteristics, solving problems, estimation, and independent construction. In 2004, some requirements dealing with topics (e.g., in algebra) that were a focus of the 1998 mathematics curriculum were reduced if they

were similar to those addressed in the basic school curriculum. Also, there was an increased emphasis on the use of mathematics concepts and terminology, rather than on memorizing mathematics facts. According to the 2004 national mathematics curriculum,⁶ the focus in **primary school** is on the following.

- Developing students' visual and logical thinking, imagination, mathematics language, and forming the subject skills necessary for the successful solution of educational and practical problems and future education.
- Mastering foundations of mathematics knowledge and forming initial ideas of mathematics as part of a universal culture.
- Developing interest in mathematics and aspirations to use mathematics knowledge in students' daily life.

Compulsory minimum content for primary school (grades 1–4) mathematics education includes the following topics.

Numbers and calculations

- Count objects; learn the name, sequence, and meaning of numbers from 0 to 1,000,000; classes and categories; understand number relations, such as “equal to”, “more than”, or “less than”, and illustrate these relations using signs ($=$, $<$, and $>$).
- Learn addition, subtraction, multiplication, and division of numbers, and use corresponding terms; addition and multiplication tables; relations (e.g. “more than”, “less than”, etc.); division with a remainder; and arithmetic operations with zero.
- Determine the order of operations in numerical expressions and define values of numerical expressions with or without brackets.
- Rearrange summands in the sum and multipliers in a product; group summands in the sum and multipliers in the product; multiply the sum of a number and number for the sum; and divide the sum into a number.
- Make oral and written calculations with natural numbers; use the properties of arithmetic operations in the performance of calculations; define an unknown component of arithmetic operations; learn ways of examining; and learn about the correctness of calculations.
- Compare and order subjects based on different attributes, such as length, weight, capacity, and time; learn units of length, weight, capacity, and time; and learn relations between units.
- Establish dependencies between the values that describe processes, such as movements, work, and purchase; construct elementary logical expressions such as “and”, “if”, etc.; and solve text problems by using arithmetic (with the support of schemes, tables, brief records, and other models).

Spatial relations, geometric figures, and geometric measurements

- Determine spatial relations, such as above-below, to the left-to the right, from above-from below, closer-further, in front-behind, before, after, between, etc.
- Recognize and draw geometric figures, including point, line, segment, angle, polygons, etc.; recognize circumference and circles and cubes and spheres; be able to measure the length of a segment and construct a segment of a given length; calculate the perimeter of a polygon, area of a geometric figure, and units of an area; and calculate the area of a rectangle.

By the end of primary school, students must meet the following achievement requirements in mathematics.

- **Know/understand** the sequence of numbers up to 100,000; the table of addition and subtraction of digits; multiplication tables and the division of digits; and rules regarding the order of operations in numerical expressions.
- **Be able to** read, write down, and compare numbers up to 1,000,000; represent multiplace numbers in an expanded form using knowledge of place value; use mathematics terminology; carry out arithmetic operations orally with results up to 100; carry out division with a remainder up to 100; carry out written calculations (addition and subtraction and multiplication and division of multiplace numbers into one- and two-digit numbers); calculate with zero; calculate the value of numeric expressions containing two to three operations (with and without brackets); examine the correctness of executed calculations; solve text problems using arithmetic (no more than two operations); use a ruler to draw a segment of a given length and measure the length of the given segment; identify geometric figures and draw them (using a ruler and by hand); calculate the perimeter and area of a rectangle or square; compare measurements based on their numerical values; and express given measurements in various units.
- **Use acquired knowledge and skills in practical activities and daily life to** orient oneself to a surrounding space (e.g., plan a route); compare and order objects by different attributes, including length, area, weight, and capacity; define time (in hours and minutes); solve problems connected with household situations (to purchase, measure, weigh, etc.); estimate subjects' approximate sizes; and perform constructive activities (application of different geometric figures).

In **basic school** or **lower secondary school** (grades 5–9), principal changes in mathematics education involve a more practical orientation toward teaching the subject, including statistics and probability in all textbooks, and the inclusion of mathematics items connected to real-life situations.

In **basic school**, mathematics education is directed toward achieving the following goals.

- Mastering the system of mathematics knowledge and the skills necessary for its application in practical activities, studying related subjects, and the continuation of education.

- Intellectual development, the formation of characteristics necessary for a productive life in a modern society, such as clearness and accuracy of thinking, critical thinking, intuition, logical thinking, elements of algorithmic culture, spatial notions, and the ability to overcome difficulties.
- Formation of notions about ideas and methods of mathematics as the universal language of science and technology and means of simulating phenomena and processes.
- Developing one's attitude toward mathematics as part of a universal culture.

Compulsory minimum content for basic school mathematics education includes the following four sections.

- *Arithmetic*: natural numbers, fractions, rational numbers, real numbers, word problems, measurements, approximations, and estimations.
- *Algebra*: algebraic expressions, properties of powers, equations, inequalities, solving word problems algebraically, number sequences, functions, and coordinates.
- *Geometry*: basic geometry concepts and theorems, angles, lines, circumference and circles, intuitive ideas of spatial bodies, triangles, trigonometry, quadrangles, polygons, geometric measurements, areas of plane figures, volumes of solids, vectors, geometric transformations, and geometric construction using a ruler and a compass.
- *Elements of logic, combinatorics, and statistics and probability*: proofs, sets and combinatorics, and statistical data and probability.

By the end of basic school, students must meet the following achievement requirements in mathematics (Exhibit 1).

Exhibit 1 Mathematics Requirements for Basic School in the Russian Federation

General Facts and Methods	
Know/understand	Mathematical proofs and algorithms; the application of mathematical formulae, equations, and inequalities for solving mathematical and practical problems; the probabilistic character of many laws of the surrounding world; examples of statistical regularities and conclusions; how geometry has arisen from practical geodetic problems; examples of geometric objects and statements about them that are important for practice, and real-life problems
Arithmetic	
Be able to	Carry out arithmetic operations orally; pass from one form of recording numbers to another form; compare and carry out arithmetic operations with rational numbers; find, in simple cases, values of powers with an integer exponent and roots; find values of numeric expressions; find approximate integers and decimals; use basic units of length, weight, time, speed, area, and volume; and solve text problems, including problems involving ratios and proportions, fractions, and percents
Use acquired knowledge and skills in practical activities and daily life to	Solve simple practical problems using reference materials, a calculator, and a computer; orally estimate the result of calculations; examine the result of calculations using various ways; and interpret results in view of the restrictions connected with properties of considered processes and phenomena

Exhibit 1 Mathematics Requirements for Basic School in the Russian Federation (Continued)

Algebra	
Be able to	Compose, transform, and find values of algebraic expressions; carry out operations with powers and polynomials and algebraic fractions; transform and calculate values of numeric expressions containing square roots; solve equations and systems of equations, inequalities, and systems of inequalities; solve word problems using algebraic methods; determine coordinates of a point and locate points on the Cartesian plane; recognize arithmetic and geometric progressions and solve problems using formulas of the general term and the sum of the first several terms of a progression; find values of the function represented in various forms and define properties of the function using its graph; use a graphic way for solving equations, systems, and inequalities; and draw graphs of studied functions
Use acquired knowledge and skills in practical activities and daily life to	Calculate using formulae, compose formulae, and express the relations between real data; find necessary formula in reference materials; model practical situations and research constructed models using algebraic methods; describe dependences between physical variables in simple practical situations using corresponding formulae; and interpret graphs representing real dependences between variables
Geometry	
Be able to	Use geometric language for description of subjects in the surrounding world; recognize geometric figures and distinguish their reciprocal location; draw geometric figures; carry out drawings according to the context of a problem; realize transformations of figures; recognize in drawings, models and the environment basic spatial bodies and draw them; draw sections and evolving spatial bodies; carry out operations above vectors and calculate length and the coordinates of a vector and an angle between vectors; calculate values of geometric sizes (lengths, corners, areas, and volumes) and define values of trigonometric functions for angles from 0° to 180° ; find values of trigonometric functions using a value of one of them; find angles and the areas of triangles, lengths of broken lines, arcs of a circumference, and areas of basic geometric figures and figures composed of them; solve geometric problems using studied properties of figures and relations between them, apply additional constructions, algebraic and trigonometric methods, and ideas of symmetry; reason convincingly when solving problems, use known theorems and find opportunities for their use; and solve elementary planimetric problems in space
Use acquired knowledge and skills in practical activities and daily life to	Describe real situations in the language of geometry; calculate with elementary trigonometric formulas; solve geometric problems using trigonometry; solve practical problems connected with geometric measurements (using, if necessary, reference books and instruments); and make constructions using geometric tools (a ruler, a set square, a compass, and a protractor)
Elements of Logic, Combinatorics, and Statistics and Probability	
Be able to	Fulfill simple proofs; receive the elementary conclusions from known or received statements; estimate the logical correctness of the reasoning, use examples for illustration and counterexamples for refutation of statements; extract the information represented in the form of tables, diagrams, and graphs; compose tables and draw diagrams and graphs; solve combinatorial problems by systematically sorting possible outcomes and using the rule of multiplication; calculate average values of results of measurements; find the frequency of events using one's own observations and given statistical data; and find the probabilities of random events
Use acquired knowledge and skills in practical activities and daily life to	Defend a proof orally; recognize logically incorrect reasoning; analyze real numerical data presented in the form of diagrams, graphs, and tables; record mathematical statements and proofs; solve practical problems in daily and professional activities using operations with numbers, percents, lengths, areas, volumes, time, and speed; solve educational and practical problems demanding systematic sorting of possible outcomes; compare chances of random events occurring, estimate the probability of random events in practical situations, and match a model to a real situation; and understand statistical statements

The Science Curriculum in Primary and Lower Secondary Grades

Summary of National Curriculum Guides for Science Through Eighth Grade

In **primary school** (grades 1-4), science education is provided through a course called “the surrounding world”, in which science is integrated with social studies (about 70% science content).

In the last decade, the content of science education in primary school has focused on creating more balance between different science knowledge areas (the proportion of geographic, physical, and chemical knowledge was increased) and emphasizing the nature of science and its methods. As a result, changes were made in instruction, such as more use of inquiry, projects, and group methods oriented toward intellectual and personal development.

According to the national science curriculum of 2004,⁷ the goals for studying the surrounding world in **primary school** are the following.

- Develop skills to observe objects from the surrounding world, describe their characteristics, make analyses and generalizations, and solve problems.
- Master knowledge of the surrounding world, including the unity and differences between nature and society, and understand humans and their place in nature and society.
- Develop positive attitudes toward the surrounding world, the environment, and intellectual and moral culture, and develop patriotic feelings and the need to participate in creative activities in nature and society.

The compulsory minimum content for primary school science education includes the following topics.

- *Surrounding world*: understand how a human being recognizes nature, society, and oneself.
- *Primary school student*: learn the daily schedule of a student, how to get to school, rules about organizing homework, personal hygiene, caring for one’s health, and safe behavior.
- *Nature*: learn about living and nonliving things; natural phenomena; the seasons; the weather; solids, liquids, and gases; water in nature; land forms; plants; animals; variability; conditions for life; and the interconnectedness of plants and animals.
- *Human beings and nature*: understand the structure and main functions of human organisms and the influence of human activities on nature.
- *Earth—our planet*: learn about the sun, sources of light and heat, and conditions for life on Earth.

By the end of primary school, students must meet the following achievement requirements in science.

- **Know or understand** the main properties of air and water; basic conditions for living organisms; rules for caring for one's health; and basic rules of behavior at school, on roads, and in the water.
- **Be able to** determine the characteristics of different objects in nature (color, shape, and relative sizes); make distinctions between living and nonliving objects in nature; define the parts of a plant; give examples of representatives of different groups of plants and animals and describe their basic features; and show continents, oceans, mountains, plains, seas, and rivers on a map and globe.
- **Use acquired knowledge and skills in practical activities and daily life to** enrich life experiences and solve problems using observation, measurement, and comparison; orient oneself in a locality with the help of a compass; determine the temperature of air, water, and the human body with the help of a thermometer; establish relations between seasonal changes in living and nonliving nature; take care of plants and animals; follow the rules of health care and safe behavior; evaluate the influence of humans on nature, follow the rules of behavior in nature and participate in the conservation of nature; and satisfy cognitive interests and search for additional information about their native land, native country, and our planet.

After the transition in 1992 to compulsory basic education, the structure of the curricula for biology, physics, and chemistry was changed to provide graduates of **basic school** (grades 5–9) with a complete system of science knowledge. Some topics, such as nuclear physics, organic chemistry, or evolution, were introduced into the basic school curriculum. More emphasis was given to the humanitarian role of natural sciences, scientific methods of investigation of nature, the role of a person in the process of thinking about nature, and the use of achievement in science.

The goals for science education in **basic school** are summarized as follows.

- Acquire knowledge about natural phenomena, basic science concepts, relations, laws, methods of thinking about nature, and the role of science in the human life.
- Master the skills of using science knowledge to explain various phenomena and processes and the principles of using basic technical equipment to solve problems; conduct observations and experiments; represent experimental results in different forms and reveal empirical relations; and use equipment, devices, and instruments.
- Develop cognitive interests and intellectual and creative abilities in the process of observations; conduct investigations, solve problems, and independently acquire knowledge, working with different sources of information.
- Develop positive attitudes toward the surrounding world and an environmental culture, recognize the laws of nature and the necessity of prudent use of scientific

and technological achievement for further development of society, and develop respect for scientists as well as a positive attitude toward science as part of culture.

- Use one's knowledge and skills in practical activities and daily life for the conservation of nature, caring for one's health, and safe behavior.

The compulsory minimum content for basic school science education is summarized below for all science subjects by the main topics studied.

- *Biology*: biology as part of the natural sciences; biological methods; characteristics of living organisms; the system, diversity, and evolution of living nature; human biology and health; and the interaction of organisms and the environment.
- *Geography*: sources of geographical information (geography as part of the natural sciences and geographic models); the nature of the Earth and humans (Earth as a planet); the Earth's crust and lithosphere; the hydrosphere, atmosphere, biosphere, and soil (the geographic shell of the Earth); continents and oceans; nature management and geocology; and the geography of Russia.
- *Physics*: physics and physical methods of nature study, mechanical phenomena, thermal phenomena, electromagnetic phenomena, and quantum phenomena.
- *Chemistry*: methods of studying substances and chemical phenomena, substances, chemical reactions, the elementary basis of inorganic chemistry, primary ideas about organic substances, the experimental basis of chemistry, and chemistry and life.

For all science subjects, the standards include detailed, formulated requirements that basic school students must achieve. For the sake of brevity, only the basic school achievement requirements for **chemistry** are given as an example in Exhibit 2.

Exhibit 2 Chemistry Requirements for Basic School in the Russian Federation

Know/understand	<ul style="list-style-type: none"> • Chemical symbols of chemical elements; formulas of chemical substances and chemical reactions; main chemical concepts: chemical elements, atoms, molecules, relative atomic and molecular mass, ions, chemical relations, substances, classification of substances, mole, molar mass, molar volume, chemical reaction, classification of reactions, electrolyte and nonelectrolyte, electrolytic dissociation, and oxidation-reduction; and the main chemical laws regarding conservation of mass, constant composition, and the periodic law
Be able to	<ul style="list-style-type: none"> • Name chemical elements and compounds of studied classes • Explain the physical meaning of a chemical element's atomic number, numbers of a group, and period to which the given element belongs; patterns of change in element properties in the limits of small periods and main subgroups; and the essence of the reaction of ion exchange • Characterize chemical elements and the structure of their atoms (from hydrogen to calcium) on the basis of their position in Mendeleev's periodic table; the relation between composition, structure, and properties of substances; and the chemical properties of the main classes of nonorganic substances • Determine the composition of substances from their formulas, how a substance belongs to definite class compounds, types of chemical reactions, valence and degree of oxidation of elements in compounds, and the possible reaction of an ion exchange • Represent formulas of nonorganic compounds of studied classes, models of the structure of atoms in the first 20 elements of Mendeleev's periodic table and equations of chemical reactions

Exhibit 2 Chemistry Requirements for Basic School in the Russian Federation (Continued)

Be able to	<ul style="list-style-type: none"> • Use chemical equipment safely • Understand experiments about oxygen, hydrogen, carbon dioxide, ammonia, solutions of acids and bases, and chloride, sulfur, and carbonate ions • Calculate mass proportions of chemical elements using the formula of compounds and mass proportions of substances in a solution as well as the quantity of a substance, volume, or mass using the quantity of a substance, volume, or mass of a reagent or the reaction products
Use acquired knowledge and skills in practical activities and daily life to	<ul style="list-style-type: none"> • Safely use substances and materials, develop ecologically literate behavior with regard to the environment; evaluate the influence of chemical pollution of the environment on humans; and critically evaluate substances used in everyday life and make solutions of a given concentration

Instruction for Mathematics and Science in Primary and Lower Secondary Grades

Instructional Time

According to the national curriculum for general secondary education, mathematics and science are compulsory subjects. The school year in primary school is 33 weeks and class periods are 35–45 minutes. In basic school, the year is 35 weeks, and class periods are 45 minutes. The school year usually starts at the beginning of September and finishes at the end of May.

Mathematics is taught four times a week in primary school (grades 1–4) and five times a week in basic school (grades 5–9). In primary school, science is taught two times per week for 4 years. In basic school, science is taught as an integrated subject in grade 5 (two classes per week); in grade 6, as two separate science subjects (biology and geography), with two classes per week for each subject; in grade 7, as three separate subjects (biology, geography, and physics), with two classes per week for each subject; and in grades 8 and 9, as four subjects (biology, geography, physics, and chemistry), with two classes per week for each subject.

The national curriculum, in addition to the federal component, includes a regional component, where about 10 percent of instructional time may be spent on different subjects including mathematics and science education according to regional priorities. This additional time allows students to learn more about the nature of their regions, and teachers can be involved in activities that develop instructional materials using the regional context.

Grade at Which Specialist Teachers for Mathematics and Science Are Introduced

The first time students have specialist teachers for mathematics and science is in basic school at grade 6.

Instructional Materials, Equipment, and Laboratories

Decisions about the organization of the learning process and its provision (materials, textbooks, equipment, etc.) are made at the school level in accordance with state and regional norms and requirements. Textbooks are chosen from the federal list of

recommended textbooks, which are approved by specialists from the Russian Academy of Sciences and the Russian Academy of Education.

Improving the experimental and practical skills of students, as well as the application of mathematics and science knowledge in everyday life, is directly connected with the quality of the equipment at schools. The problems connected with the shortage of school materials and equipment in Russia, indicated in TIMSS 1995, 1999, and 2003, have begun to be solved in recent years. Various national projects from 2005–2008 were aimed at better equipping schools, especially with science laboratories.

Use of Technology

In the last decade of Russian education, information and communication technology (ICT) was introduced into general education. The federal and regional projects, such as the Development of Common Educational Information Environment: 2001–2005,⁸ Electronic Russia,⁹ and the Informatization of the Educational System,¹⁰ were aimed at developing technology infrastructure, developing electronic educational resources, providing professional development for teachers in technology, and introducing ICT into the learning process and school management. Some results of these activities included a national Internet portal, electronic textbooks, and a nationally distributed electronic library of information resources.¹¹

According to the Ministry of Education and Science, all schools will have access to the Internet by the end of 2008. In the national curriculum, calculators and computers are recommended for use in mathematics and science classes for solving practical quantitative problems and Internet resources are recommended for searching for information, distance learning, and preparing for national examinations.

Homework Policies

Traditionally, homework is assigned for each lesson in primary and basic school. In practice, in grade 4, teachers assign mathematics and science homework for 15–30 minutes and in grade 8, for 30 minutes.

Teachers and Teacher Education

Education and Training for Fourth and Eighth Grade Mathematics and Science Teachers

There are several different ways to become a primary or secondary education teacher. Teacher education for primary school may include 5 years of formal education at a higher education institution with specialization in pedagogy, methodology, and instruction in primary education teaching. It also may include 4 years of a bachelor's program at a higher education institution with specialization in pedagogy; 2 years at a pedagogical college having entered the college following graduation from secondary school; or 4 years at a pedagogical college, having entered college following graduation from basic school. In recent years, earning a diploma from a higher education institution has become more popular among primary school teacher candidates.

Teacher education for basic and secondary school in mathematics and science also may include 5 years of formal education at a higher education institution with qualifications

as a teacher of mathematics, physics, chemistry, biology, or some combination of these; 4 years of higher education, with a Bachelor of Physics-Mathematics (or Science) Education; or 6 years of higher education with the qualification of Master of Physics-Mathematics (or Science) Education. A student must cover the training program in accordance with the state educational standards of higher professional education, prepare and defend his or her graduate qualification work, and pass the state examinations.

Teacher Professional Development in Mathematics, Science, and Technology

Professional development is no longer compulsory and is changing its orientation to be in line with the new goals of education, with a switch in emphasis from subject content to student development, so that teachers have more training in active learning strategies and child development. Teachers also are taught to use ICT in the learning process.

According to the state policy on education, teachers' work will be evaluated not by their knowledge level but by the main developmental indicators of their students. Accordingly, during professional development, teachers learn new ways of assessing student achievement and development.

Examinations and Assessments

National or Regional Examinations

The general education system has a very flexible system of school examinations. To be awarded the basic school certificate, students must pass four examinations: compulsory national examinations in mathematics and Russian and two examinations in subjects selected by the students themselves. To be awarded the certificate of secondary school completion, students must pass five examinations: compulsory national examinations in mathematics and Russian and three examinations in subjects selected by the students themselves. Examinations in science subjects are not compulsory. Students may choose any science subject for examination at grades 9 and 11, which are prepared centrally by the test developers from the Federal Institute of Educational Measurement.

Standardized national examinations, known as unified state examinations, recently have been introduced, combining the general secondary education graduate examinations with higher education entrance examinations. Unified state examinations will be compulsory for all secondary school graduates beginning in 2009.

In addition to the national examinations, a school may set an examination on every subject at any basic or secondary school grade, which may be administered in oral or written forms and include multiple-choice and short- or extended-response questions and essays.

Other Tests

Introduction of the state educational standards has changed the procedure for school accreditation, increased the role of student assessment, and slightly changed the emphasis from assessment of separate science subject knowledge to assessment of scientific literacy and the nature of science knowledge and skills.

With the aim of looking for talented students interested in mathematics and science, more Olympiads and other competitions have been organized. In the last decade, more attention is focused on project and investigation results, with an integrative nature, than on subject knowledge acquired.

Monitoring Individual Student Progress

Formative and summative assessments are conducted to assure compliance of student achievement with curriculum requirements and diagnose student progress. The timing and form of assessment, as a rule, are chosen by the school. Sometimes, assessment results are used for teacher or school accreditation. Generally, the summative assessment takes place at the end of each school year in each school subject. Assessment formats include oral examinations; presentations; short-answer, extended-response or essay questions; and multiple-choice tests. Schools usually use teacher-made tests, locally developed tests, or tests developed centrally and published as special supplementary materials.

Innovations in assessment arising from general education reform include the introduction of a qualitative system of assessment without grades or marks in primary school and a shift in the orientation of assessment from absolute achievement to the dynamics of student achievement throughout primary school.

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Saudi Arabia

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Introduction

Overview of Education System

Saudi Arabia was founded in 1932 by King Abdalaziz Al Saud, when he united the two parts of his state under one government. The official name of the country, which came from the royal family name, is the Kingdom of Saudi Arabia.¹ Saudi Arabia is the largest country in the Middle East and occupies about 2.25 million square kilometers, or about four fifths of the Arabian Peninsula, stretching from the Arabian Gulf in the east to the Red Sea in the west. The population, according to the latest census conducted in 2004, is 22,673,538, of which 16,529,302 (72.9%) are Saudi and 6,144,236 (27.1%) are non-Saudi.²

The Ministry of Education was established in 1953. It was given the specific task of expanding the national school system for male students, with the goal of modernizing it and making it comparable to education systems in Western countries.³ In 1960, the General Administration of Girls' Education (GAGE) was established independently of the Ministry of Education. However in 2002, GAGE was put under the administration of the ministry.

The structure of the education system, as originally created by the ministry, offered 6 years of elementary and 5 years of secondary education, but was later changed to 6 years of primary school (grades 1–6), 3 years of intermediate school (grades 7–9), and 3 years of secondary school (grades 10–12). Basic compulsory education in Saudi Arabia is for all children ages 6 to 15.

Saudi Arabia has three different types of schools—public, private, and international. The Ministry of Education operates general elementary, intermediate, and secondary education schools, although there are a number of specialized institutes.⁴

The education system is centralized, with all authority held by the Ministry of Education. Therefore, the 42 districts of education distributed throughout the country do not have decision-making authority. Curricula, teacher training and appointments, and school inspections are all centrally determined by specific departments within the Ministry of Education.

The development of the education system is aligned with the general development plan of Saudi Arabia, which operates in 5-year periods. Within the first development stage, the education system was charged with three objectives: “(a) to provide at least basic education for all citizens; (b) to provide students with the skills required by the changing needs of the economy; and (c) to educate students in the beliefs, practices, and values of Islamic culture.”⁵ The most recent 10-year plan (2004–2014) includes the following general goals.

- Including all students from ages 6–18 in the stages of public education
- Preparing students for positive cultural, educational, and teaching interactions, both locally and internationally, and striving to achieve great developments in the fields of mathematics and science for all groups
- Improving the quality of the education system
- Developing school curricula according to Islamic values and with the aim of building students’ character and providing them with knowledge and systematic thinking skills
- Improving the quality of both male and female teachers
- Developing the educational environment and modernizing the school plan
- Developing information and communication technology infrastructure and using it in the processes of teaching and learning
- Expanding social participation in education.⁶

Emphasis on Mathematics and Science

The Ministry of Education is strongly committed to improving mathematics and science education. A sign of this commitment is the minister’s decision to participate in the ongoing cycles of the TIMSS assessment. Efforts also are being made to improve mathematics and science instruction. Following an intense appraisal of mathematics and science teaching, educators have set up a comprehensive program of reform that contains two parts. The first is targeted at curriculum improvement and the second at teacher training.

The education system is currently undergoing reform in a number of areas and through different channels. One aspect under reform is the curriculum for mathematics and science for all grade levels (1–12). Saudi’s participation in the TIMSS assessments is part of the developmental approach process. Seventy-five percent of mathematics and science curricula content relates to content that is assessed in the TIMSS tests.

Overarching Policies Related to Education and the Curriculum for Mathematics and Science

In the early stages of developing the mathematics and science curricula, as well as the curriculum in other subjects, Saudi education adapted the curricula of other Arab countries, especially those of Egypt, but added more emphasis to religious subjects.⁷

The first attempt to develop the science curriculum was in the early 1970s, when the Ministry of Education contacted the Science and Math Educational Center at the American University in Beirut, Lebanon to establish a comprehensive plan to develop science and mathematics for Saudi schools.⁸ This project involved analyzing academic achievement and perception levels for intermediate and secondary school students, determining the desired subjects and units in each course, preparing teachers' textbook guides, continuing evaluation of the work with educators from Saudi universities, and offering workshops.⁹

Recently, the Ministry of Education established the General Project for Curriculum Development, which aims to dramatically improve education by making core changes to the curriculum. The goal is to make each curriculum better suited to quick growth and development, locally and internationally, and to provide effective methods for accomplishing educational policy by developing an integrated education system. This can be achieved by effectively interacting with new educational technologies, benefiting from other experiences, specifying required skills to be learned by students at every educational level, linking information to everyday life, developing critical thinking methods and performance skills, and developing required skills for productive work.¹⁰ The 3-year project included training courses and specialized workshops, attracted scientific professionals, and facilitated financial opportunities. The project also promoted mutual visits between committees in the Gulf region and other countries internationally, field studies and research, reviews of other countries' experiences, ratings of the current curricula, and coordination with all concerned sectors in Saudi Arabia, including private and governmental sectors as well as educational institutes.¹¹

In 2008, the ministry signed an agreement with a local educational company, *Al-Obaikan*, to develop mathematics and science curricula. In 2009, the new curriculum will be implemented in a number of schools in the kingdom and become the national curriculum.

The Mathematics Curriculum in Primary and Lower Secondary Grades

Summary of National Curriculum Guides for Mathematics Through Eighth Grade

In mathematics, a single curriculum framework is used consistently throughout the different levels of the education system; however, the depth of concepts and skills differ for each level of schooling. The Saudi mathematics curriculum is described in the Mathematics Curriculum Framework, which aims to develop students' mathematical abilities. The mathematics framework sets out directions for the teaching and learning of mathematics.

Exhibit 1 details the mathematics concepts and skills to be covered by the end of **primary (grades 1–6)** and **intermediate school (grades 7–9)**.

Exhibit 1 Mathematics Curriculum for Primary and Intermediate Schools in Saudi Arabia

Primary Mathematics	Intermediate Mathematics
Numbers and Algebra	
Counting	Negative numbers, integers, rational and real numbers, and the four operations
Numbers, fractions, and decimals	Prime numbers
The four operations	Order of operations
Factors and multiples	Use of symbols: $<$, $>$, \leq , \geq
Short and long division	Approximation and estimation
Order of operations	Percentage
Approximation and estimation	Ratio and direct and inverse proportion
Percentage	Map scales
Ratio	Rate and speed
Speed	Algebraic expressions and formulae
Algebraic expressions with one variable	Algebraic manipulation (linear and quadratic)
	Functions and graphs (linear and quadratic)
	Linear equations with one unknown
	Simultaneous linear equations with two unknowns
	Quadratic equations
	Linear inequalities with one unknown
	Set language and notation
Geometry and Measurement	
Measurement of length, mass, volume, time, and angles	Properties and construction of simple geometric figures
Area and perimeter of triangles and circles	Angles associated with parallel lines
Volume of cubes and cuboids	Angles of polygons
Properties of simple geometric figures	Congruence and similarity
Nets of simple solids	Area of plane figures, volume, and surface areas of 3-D solids
Line symmetry	Pythagorean theorem
Statistics and Probability	
Picture graphs, bar graphs, line graphs, tables, and pie charts (including interpretation and use of information to solve problems)	Data handling (including data collection and representation)
Simple data collection and simple analysis (frequencies)	Data analysis (including interpretation and analysis of various statistical representations)
Average	Probability

The Science Curriculum in Primary and Lower Secondary Grades

Summary of National Curriculum Guides for Science Through Eighth Grade

The Saudi Science Curriculum Framework focuses on scientific inquiry as a common basis for all domains. The science curriculum provides knowledge, thinking skills (understanding and application), and scientific ethics and attitudes. It aims to prepare students to transfer information, knowledge, and skills to their everyday lives and help society and the environment by using and employing scientific concepts.

As mentioned above in the section on mathematics, in science, a single curriculum framework is used in primary and intermediate schools; however, there is a difference in the depth of knowledge and skills taught at each level of schooling. The science curriculum has five topic areas: biology, chemistry, physics, earth and space, and health.

Exhibit 2 presents the science concepts and skills included in the **primary (grades 1–6)** and the **intermediate school (grades 7–9)** curriculum.

Exhibit 2 Science Curriculum for Primary and Intermediate Schools in Saudi Arabia

Primary Science	Intermediate Science
Biology	
Living and nonliving things	Classification of plant and animal life
Life cycles of plants and animals	Photosynthesis and respiration
Units of life	Transport in living organisms
Reproduction in plants and animals	Cells: structure, function, and organization
Digestive and musculoskeletal systems	Digestion in animals
Respiratory and circulatory systems	Sexual reproduction in human beings
Plant parts and functions	
Photosynthesis and respiration	
Classification of organisms and materials	
Chemistry	
Matter	Elements, compounds, and mixtures
Water	Classification of matter
	Solutions and suspensions
	Simple concepts of atoms and molecules
	Chemical changes
	Particulate model of matter
	Nutrient cycles in ecosystems
Physics	
Materials	Sources and storage of energy
Light	Light
Heat	Force and related concepts
Magnets	Effects of heat
Simple machines	Transmission of heat
Forces	Sound
Electrical systems	Electricity
Forms of energy and conversions	Use of measuring instruments
	Physical quantities and units
Earth and Space	
Day and night cycles	Simple concepts of populations, community, and ecosystems
Environmental impact	
Ecology	Energy transfer process in the ecosystem
Health	
Common diseases	Hereditary diseases

Instruction for Mathematics and Science in Primary and Lower Secondary Grades

Instructional Time

Students receive 4 hours of instructional time each week in mathematics and in science.

Instructional Materials, Equipment, and Laboratories

Each school is equipped with free textbooks and instructional materials as well as science and computer laboratories.

Use of Technology

Computer use as a formal subject is introduced in grade 10, but is practiced as an extracurricular activity in all grades.

Teachers and Teacher Education

Education and Training for Fourth and Eighth Grade Mathematics and Science Teachers

All teachers must hold a bachelor's degree in order to teach in Saudi schools. They also must hold a practicing teacher's certificate and reach or exceed a designated score on the teacher minimum competency test, which is administered twice a year. Every year, the Ministry of Education announces the number of teachers needed for schools in all subjects.

Teacher Professional Development in Mathematics, Science, and Technology

Teachers always have opportunities to enroll in ongoing professional development programs. These programs help teachers improve their teaching skills and strategies, including those relevant to information technology. Teachers involved with the TIMSS assessment are required to participate in a comprehensive program that covers test development and administration. This program helps ensure the quality of test taking and eliminates the errors arising from students being given unclear or inaccurate instructions at the time they take the tests.

Examinations and Assessments

National or Regional Examinations

Until the late 1990s, summative assessment, which focused on generating a grade that reflected student performance, was the dominant assessment practice in Saudi schools. Therefore, the examination system, established when the general educational department was founded, was the first tool of educational assessment.¹² However, recently, continuous assessment has been gradually implemented in primary schools.

The first change to the examination system was to measure student performance by averaging student results on an examination that was conducted every 3 months.¹³ In the next change to the examination system, the decision was made to divide the academic year into two semesters. At the end of each semester, there is an examination that covers one half of the requirements of each subject. Students receive marks at the end of each semester, which determine their grade for the whole year. Of the total mark

for each subject, 70 percent is from a written examination at the end of each semester, 20 percent is determined by a midterm test, and 10 percent is based on student participation and homework completion. Final examinations for grades 1 and 2 are oral, except in mathematics and science. For grades 4 to 6, all examinations are written, except in reading and some religious subjects.¹⁴ The minimum passing mark is 40 percent of the total mark for social and science subjects and 50 percent for other subjects. If a student fails to achieve the minimum required mark in a subject at the end of the year, he or she may take another examination again at the end of summer recess. However, if a student again fails to attain the minimum passing percentage, he or she has to repeat the whole year, restudying all subjects taught in that year, including those already passed.¹⁵

There was an important change in the assessment system in 1999, when students in grades 4 to 9 were considered to have passed their subjects if they obtained at least 70 percent of the minimum passing mark in just two subjects (excluding religion and language subjects). Also, continuous assessment, using alternative testing methods, was suggested for grades 1 to 3. The syllabus of applied continuous assessment had three phases. The first phase, beginning in the first semester of the 1998 school year, was the initial experimental phase when some education departments were given the opportunity to choose the appropriate way to implement the new assessment method. The second experimental phase began in the second semester of that same school year, with a large number of education departments following specific methods for implementation. In the last phase in 1999, continuous assessment was applied in all primary schools from grades 1 to 3.¹⁶ The goals of the Ministry of Education in using continuous assessment are described below.¹⁷

- Linking the assessment process with instructional procedures
- Using authentic assessment in the classroom
- Assessing student performance in different situations within a semester
- Applying criterion-referenced assessment approaches based on important learning outcomes
- Including students and their parents in the assessment process.

Monitoring Individual Student Progress

Continuous assessment, as it has been used in Saudi primary schools, is dependent on two factors. It provides teachers with a guide for each subject, including the expected skills in each subject, and outlines the basic skills and knowledge necessary to promote a student to the next level. Secondly, different forms of continuous assessment are used to assess skills and knowledge, and student progress is reported twice per semester, with an assessment report sent to parents each time. The syllabus also gives the School Consular Committee authorization to assess cases where students do not achieve the minimum level of expected skills and knowledge and decide whether to promote them to the next level, or keep them in the same grade and transfer them to supported programs.

The first amendments to the new General Project for Curriculum Development were in 2006, after “a comprehensive review of the previous bylaw of student assessment”.¹⁸ The most important changes, according to the new bylaw concerning assessment, were in the assessment of middle and secondary schools. Changes included replacing the midterm test with multiple short tests conducted during the term and other forms of continuous assessment. If a student fails more than two subjects in the intermediate or first grade in secondary school, he or she can retest in two subjects of his or her choice on the condition that he or she obtains no less than 70 percent of the minimum mark in each subject. No substantial changes in primary school assessment have occurred as a result of the new bylaw. The main change in assessment in primary schools is the extension of continuous assessment to upper levels of primary schools (grades 4–6), which will be implemented gradually from 2006 to 2008.¹⁹

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Scotland

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Introduction

Overview of Education System

The First Minister for Scotland is responsible for the overall supervision and development of the education system in Scotland and reports to the Scottish Parliament. Day-to-day responsibility for education is delegated to the Cabinet Secretary for Education and Lifelong Learning, who is supported by two Ministers—the Minister for Children and Early Years and the Minister for Schools and Skills. Policy implementation is overseen by the Scottish Government Education and Lifelong Learning Directorates,¹ which are responsible for education in schools, colleges, and universities, as well as for workplace training and lifelong learning. Ministers are advised by Her Majesty’s Inspectorate of Education² and the national bodies dealing with the development of the curriculum (Learning and Teaching Scotland)³ and public examinations (the Scottish Qualifications Authority).⁴ Local responsibility for educational services in schools rests with the 32 Scottish local authorities.

Mathematics and science, like all curriculum subjects, are funded centrally. In addition, science has ring-fenced funding for teachers’ professional development. This means that the Scottish Government financially supports the Scottish Schools Equipment Research Centre with its provision of continuing professional development courses for teachers and technicians.⁵

Scotland’s national curriculum is nonstatutory. Responsibility for what is taught lies with local authorities and schools, taking into account national guidelines and advice provided by the Scottish Government and by Learning and Teaching Scotland. Teachers working with students in Scottish primary schools and in the first 2 years of secondary education are currently guided by the recommendations of the 5–14 national guidelines on teaching and assessment.⁶ The curriculum is being reviewed and revised following the publication of *A Curriculum for Excellence* in November 2004.⁷ Schools will be working towards the implementation of the new curriculum, which has as its goal the creation of a seamless curriculum from ages 3 to 18, from August 2008 onwards.

Education is compulsory for students, ages 5–16. The education system includes preschool, primary, and secondary education, as well as further and higher education. Education in Scotland is free for all students. However, a small percentage of students attend private schools, which are not publicly funded (the figure in 2006 was 4% across the primary and secondary sectors).^{8,9} In September 2006, there were just over 700,000 students in 2,755 publicly funded schools in Scotland.¹⁰

Children normally enter school in the academic year in which they become 5 years old. Thus, students enter the first year of primary schooling in August at age 4, if they are 5 years old before the end of the following February. In this case, parents have the option of deferring entry for a year. If students do not turn 5 until after February, then they begin school in August following their fifth birthday. There are no restrictions on entrance (i.e., there are no entrance examinations).

Primary schools, for ages 5 to 12, are organized into primary 1 to primary 7 classes (P1 to P7). Students are generally taught in mixed-ability classes by a generalist teacher. Teachers follow the national curriculum guidelines for this age group, and specialists may provide support in art, drama, music, and physical education.

In rural areas, there are a few combined primary and secondary schools. In other areas, there are a few infant schools that admit children beginning at age 3 who are then transferred to a primary school at age 5.

Almost all **secondary** education, with the exception of those schools in very remote areas, begins at age 12 and includes 4 years of compulsory education (S1 to S4), followed by an additional 2 years (S5 and S6) for those students who wish to continue their education. In the early secondary years (S1/S2, ages 12–14), setting by ability (placing a student in a class with others of a similar ability) is sometimes employed for mathematics classes but is less common in science. In S3/S4 (ages 14–16), most students are in classes grouped by broad levels of ability, and in the senior school (S5/S6, ages 16–18), classes tend to be self-selected according to the level of study, although, in some subjects, students also may be placed in classes according to their ability level. In the first 2 years, students follow the national curriculum, and beginning in S3, students follow the syllabus for national examinations.

Opportunities for higher education are provided primarily through colleges and universities. Colleges provide a wide range of vocational and nonvocational education and training opportunities, and offer several options of both further and higher education qualifications. They provide flexible learning opportunities to people of all ages, from school-age students to more mature learners. Universities and other higher education institutions provide courses for subdegrees, first degrees, the education and training of teachers, postgraduate studies at master's and doctorate levels, and at a higher level in preparation for a qualification from a professional body.

Since 2002, local authorities have been required to offer free part-time preschool education places for all children ages 3 and 4. Preschool is available in a variety of forms and in a range of settings such as nursery classes within primary schools, nursery schools, and children's centers.¹¹ Some places also are commissioned from private and voluntary

centers. According to participation rates for the 2005–06 school year, 99 percent of all eligible children had registered for preschool.¹² A curriculum framework for children, ages 3 to 5, was published in 1999 by HM Inspectors of Schools (Scotland), who have a responsibility for inspecting preschool establishments. Since 2001, the Assessment is for Learning program has been phased in, aimed at improving learning and attainment through improving the assessment *of* learning, as well as promoting assessment *for* learning and assessment *as* learning.¹³

Language and Population

In Scotland, the official language is English. There are two indigenous heritage languages: Scottish Gaelic, with almost 59,000 people who speak this language (over 1% of the population),¹⁴ and Scots, which incorporates a range of local dialects. More people in Scotland speak Scots than Scottish Gaelic, although the number has not been determined.¹⁵

The main minority ethnic groups are Pakistani, Chinese, and Indian. Community languages spoken include Urdu, Punjabi, Cantonese, Polish, Arabic, Italian, and Gaelic.^{16,17}

Second-language Instruction

The language of instruction in most schools is English. However, in September 2006, over 2,000 students were receiving at least some of the curriculum through Gaelic-medium education. This means that these students were taught all or some subjects in their schools in Scottish Gaelic.

Emphasis on Mathematics and Science

At both the grades tested in TIMSS (grades 4 and 8), science and technology form part of the curriculum area of environmental studies, while mathematics is a discrete subject in the curriculum.

Careers in science and technology are promoted through particular initiatives, such as the Scottish Space School¹⁸ and the Scottish STEMNET network, which promotes science and technology events in schools and places Science and Engineering Ambassadors in schools.¹⁹

Overarching Policies Related to Education and the Curriculum for Mathematics and Science

Teachers working with students in Scottish primary schools (P1 to P7) and in the first 2 years of education (S1 and S2) currently are guided by the recommendations of the 5–14 national guidelines on teaching and assessment. This provides a general education. The third and fourth years of secondary education (S3 and S4) have elements of specialization for all.

The current 5–14 curriculum is divided into five broad curricular areas: language, mathematics, environmental studies, expressive arts, and religious and moral education. Attainment outcomes are set out for each strand of learning within these areas.²⁰ Within each conceptual strand, detailed attainment targets provide specific statements of what

students should know and be able to do at each of six levels, A–F. These levels provide a clear indication of progression in students' learning, either in terms of specific content or broad concepts.

The aim of the current 5–14 program has been to promote the teaching of a broad, coherent, and balanced curriculum that offers all students continuity and progression as they move through school. The revised curriculum will offer a range of different experiences and outcomes in all subjects, reflecting the increasingly sophisticated needs of society and will render the previous 5–14 attainment outcomes redundant. The goal of the new curriculum is to offer students greater choice and opportunity and give teachers more professional freedom. Currently, instruction in mathematics and science, as in all other subjects, is undertaken using the 5–14 curriculum, but teachers are encouraged to consider the forthcoming 3–18 curriculum when planning their lessons. This new integrated curriculum and the experiences and outcomes it incorporates are expected to have a positive impact on attainment.

The Mathematics Curriculum in Primary and Lower Secondary Grades

Summary of National Curriculum Guides for Mathematics Through Eighth Grade

The guidelines for mathematics were last updated in 1991 (as mentioned previously, new guidelines with revised outcomes take effect from 2008–2009). The current guidelines set out a rationale for mathematics education, attainment outcomes and targets, and programs of study, as well as provide guidance on catering to the needs of particular students, assessment and recording, and specific issues in mathematics (the use of calculators and computers). Attainment outcomes describe what students can do as a result of their learning experiences. In mathematics, students are expected to develop problem-solving and inquiry skills and understand concepts and facts and techniques in three areas: information handling; number, money, and measurement; and shape, position and movement. Teachers also are expected to support their students in developing positive attitudes toward mathematics.²¹

The program of study describes a plan of action for teaching mathematics. Programs are determined at the school level and encompass a variety of teaching approaches, in order to broaden students' experience and take into account the particular needs of individual students and groups of students.

Students are expected to learn through exposition (direct explanation of ideas), discussion (learning by sharing ideas and talking things over), activity (learning by planning, doing, reflecting, and reporting), and inquiry (learning through posing and attempting to solve problems and tackling investigations). Inquiry may be teacher initiated or student initiated and is designed to develop students' skills in problem solving and inquiry and to deepen their understanding of concepts.

Exhibit 1 summarizes the current attainment outcomes in mathematics. The guidelines give further details about each outcome.²²

Exhibit 1 Attainment Outcomes in Mathematics

Problem-solving and Inquiry Skills	Concepts, Facts, and Techniques		
Problem-solving and Inquiry	Information Handling	Number, Money, and Measurement	Shape, Position, and Movement
Starting a task	Collect information	Number and number notation	Properties of two- and three-dimensional shapes
Doing a task	Organize information	Methods of calculating using number	Properties of position and movement
Reporting on a task	Display information	Patterns, sequences, and relationships	
	Interpret information	Measure	

The Science Curriculum in Primary and Lower Secondary Grades*Summary of National Curriculum Guides for Science Through Eighth Grade*

Science and technology are taught as part of environmental studies, which also incorporates social studies (related principally to aspects of history, geography, and modern studies). The guidelines for environmental studies were last updated in 2000 (as mentioned previously, new guidelines with revised outcomes take effect from 2008–2009). The current guidelines set out a rationale and framework for environmental studies and specify attainment outcomes, strands, and targets, as well as provide guidance on planning, teaching, learning, and assessing in environmental studies. They also include guidance on using information and communication technology in environmental studies and on health and safety in science education. The attainment outcomes describe what students can do as a result of their learning experiences, in terms of knowledge, understanding, and skills. They also encourage the development of informed attitudes. For each outcome, a system of strands identifies the key concepts.²³

The attainment outcomes in the science aspects of environmental studies relate to Earth and space, energy and forces, living things, and the processes of life. The attainment outcome in technology is technological capability. Some aspects of the TIMSS assessment framework for science are taught through other subjects, such as health or other aspects of environmental studies.

As in the mathematics curriculum, students learn in a variety of ways: through explanation, inquiry, activity, and discussion. They also learn in a variety of settings and contexts. For example, they may undertake a local study, a series of practical investigations, a comparative study of other times or places, or a special event or an enterprise activity. By organizing those learning activities that involve active engagement with the environment, teachers encourage their students to see the relevance of their studies to themselves, their community, and the global environment as a whole.

Exhibits 2 and 3 summarize the attainment outcomes in science and technology, respectively. The guidelines give further details about each area.

Exhibit 2 Attainment Outcomes in Science

Knowledge and Understanding			Skills	Attitudes
Earth and Space	Energy and Forces	Living Things and Processes of Life	Skills	Developing Informed Attitudes
Earth in space	Properties and uses of energy	Variety and characteristic features	Preparing for tasks	A commitment to learning
Materials from Earth	Conversion and transfer of energy	The processes of life	Carrying out tasks	Respect and care for self and others
Changing materials	Forces and their effects	Interaction of living things with their environment	Reviewing and reporting on tasks	Social and environmental responsibility

Exhibit 3 Attainment Outcomes in Technology

Knowledge and Understanding	Skills in Designing and Making	Developing Informed Attitudes
Needs and how they are met	Preparing for tasks	A commitment to learning
Resources and how they are managed	Carrying out tasks	Respect and care for self and others
Processes and how they are applied	Reviewing and reporting on tasks	Social and environmental responsibility

Instruction for Mathematics and Science in Primary and Lower Secondary Grades

Instructional Time

The academic year runs from mid-August to the end of June. For students of compulsory school age, the academic year lasts a minimum of 190 days (38 weeks). Teacher contracts allow for 5 additional days, which are devoted to teacher professional development.

Learning and Teaching Scotland produces guidelines on the structure and balance of the curriculum. The principle of balance ensures that appropriate time is allocated to each area of curricular activity and that provision is made for a variety of learning experiences. The time allocations for the current 5–14 curriculum areas consist of a minimum recommended time for each area and additional time for schools to use flexibly in order to enhance learning in any of the main curriculum areas. In primary schools, the recommended minimum allocation for mathematics is 15 percent of overall curriculum time (from a total of about 25 hours of teaching time each week). The same percentage of time also is recommended for environmental studies (incorporating society, science, and technology) at the primary level. In the first 2 years of secondary school (S1 and S2), the recommended minimum allocations across the 2 years are 10 percent for mathematics and 30 percent for environmental studies (from a total of about 27.5 hours of teaching time each week).²⁴

Instructional Materials, Equipment, and Laboratories

Programs of study are not centrally prescribed but can be developed by teachers tailored to their own schools and students, following national guidelines. Textbooks commonly are used in science teaching at grade 8 but less so at grade 4. Most teachers

use them as a supplementary resource. At both grades in mathematics, textbook use also is common, this time as a main resource. Very few primary schools in Scotland have science laboratories, which are far more common in secondary schools, with almost all secondary schools having them.

Grade at Which Specialist Teachers for Mathematics and Science Are Introduced

The age at which Scottish students first encounter specialist teachers of mathematics and science varies. At grade 4, teaching is usually undertaken by a class teacher, who may teach each subject as a discrete unit or may combine them in project-based teaching. However, a small number of primary schools employ specialist teachers. In most cases, students first encounter specialist teachers when they enter secondary school (S1, ages 12–13). At grade 8, each subject is usually taught by a specialist teacher (or team of specialist teachers).

Use of Technology

The provision of computers is widespread in Scottish secondary schools, and their use is encouraged by the curriculum guidelines. The number of computers available varies across schools, although most secondary schools have Internet access and access to technical support. In mathematics teaching, packages that develop problem solving and key skills are popular, and database and spreadsheet work also is common.

Primary schools are equally likely to have access to computers, though being smaller, these schools typically have fewer computers than their secondary counterparts. Again, most of the computers have Internet access.

The use of calculators is encouraged by the curriculum guidelines, with recommendations made about appropriate usage, including instructions that students should adopt the following routine: estimate, calculate, and check. Students are discouraged from using calculators for routine calculations, and mental arithmetic is emphasized in the curriculum. The guidelines note that there are some specific calculator skills such as reading and interpreting numerical displays that should be learned. The use of calculators to aid learning of more complex mathematics also is encouraged. Scottish teachers generally allow their students restricted use of calculators in mathematics lessons. Each school has its own policy on calculator use.

Homework Policies

While there is no centrally prescribed policy, most Scottish schools, nevertheless, expect students to undertake homework. Schools develop their own homework policy, which is usually a generic policy rather than specific to particular subjects. Most grade 8 mathematics and science teachers assign homework. At grade 4, mathematics homework also is common, though science homework is given less often at grade 4.

Guidance regarding homework is available.²⁵ The guidance is aimed at parents as well as teachers, noting that homework arrangements work best when teachers, parents or family members, and the students themselves all understand their respective roles. Therefore, schools are encouraged to let parents know what is expected of their children,

what the school expects from them, and who to contact if they are concerned about homework. The guidance provides examples of possible types of homework and also includes practical examples of how schools have encouraged students and parents to engage meaningfully with homework.

Teachers and Teacher Education

Education and Training for Fourth and Eighth Grade Mathematics and Science Teachers

There are two paths to obtaining a teaching qualification to become a primary school teacher in Scotland. Students can take a 4-year course leading to a Bachelor of Education degree. Alternatively, those who already have a university degree in a relevant subject can undertake a 36-week Professional Graduate Diploma of Education. Both programs promote knowledge and understanding of children's learning and development and include a substantial period of school experience.

To become a secondary school teacher in one or more subjects, students can take either an undergraduate course (combining subject study with teacher training) or, if they already have a degree in the subject(s) they wish to teach, a Professional Graduate Diploma of Education. Both routes include at least 18 weeks of school experience.

Newly qualified teachers undertake a probationary period of 1 year. During this period of induction, they have a reduced teaching load of 70 percent, with the remaining 30 percent of their time reserved for professional development. Competence is assessed in school at the end of the year and, if successful, the teacher then is officially registered with the General Teaching Council for Scotland. Registration is a requirement for all teachers working in publicly funded schools in Scotland.

There have been no recent teacher shortages in Scotland. A continued recruitment drive is taking place with the intention of reducing P1 to P3 class sizes in primary schools.

Teacher Professional Development in Mathematics, Science, and Technology

In 2001, the Scottish Executive created a new framework for the continuing professional development of teachers. A maximum of 35 hours of continuing professional development each year was introduced for all teachers, to be used on an appropriate balance of personal professional development, attendance at nationally accredited courses, small-scale school-based activities, or other continuing teacher professional development activities.²⁶ Subject-based professional training may focus on subject knowledge, pedagogy within a curriculum area, or contextual factors such as use of resources, including the use of technology and information and communication technology.

Examinations and Assessments

National or Regional Examinations

The Scottish Qualifications Authority administers the national examination and qualifications system.²⁷ The authority's main focus is examinations from grades 10 to 12, and it also has been responsible for designing assessment materials for students ages 5 to 14. Some of these materials are used for purposes of assessing individuals, while others are used for monitoring attainment trends.

Standard grade examinations are taken at grade 10. These include one or more external examinations together with an element of assessment carried out by the school itself and moderated by the Scottish Qualifications Agency (SQA). Typically, eight modes (subjects) are taken, including mathematical studies and applications. Students then may go into employment, vocational training, or to further study at either a school or college. The school route typically culminates in National Qualifications at a Higher level (these are referred to as Highers) in grade 11. Some schools also offer Intermediate 1 and 2 qualifications, typically in grades 9 to 11, while those students who are successful in their Highers also can take Advanced Highers in grade 12. Successful completion of the Higher Grade examinations enables students to apply for university level study, if they choose.

Standard, Intermediate, and Higher grade examinations are available in a range of subjects. Schools generally offer a range of traditional subjects, as well as newer subjects that are useful in today's workplaces, such as biotechnology, media studies, and information systems. Science awards can be a single integrated science award, or students may take separate examinations in biology, physics, and/or chemistry. Additionally, following a 2-year pilot involving up to two thirds of secondary schools, Skills for Work courses for S3 to S4 students and above were introduced beginning in August 2007 in a range of vocational subjects.

Other Tests

In addition to developing these national assessments, the Scottish Qualifications Authority works with Learning and Teaching Scotland and the Scottish Government to produce the Scottish Survey of Achievement, a sample survey of students' attainment at grades 2, 4, 6, and 8, carried out in May to June each year. Each survey gathers evidence of attainment using a range of written and practical assessments and focuses on a particular subject each year. In 2007, the focus of the survey was science, science literacy, and core skills.²⁸

The Scottish Survey of Achievement is part of Scotland's Assessment is for Learning strategy,²⁹ and separates national monitoring from classroom assessment. It is designed to provide accurate information about overall trends in achievement at the national level, with optional local authority-level information, without overburdening schools or distorting classroom practice. Therefore, it offers a means of seeing how effective education policy has been and what needs to be done to improve standards for all children.

Monitoring Individual Student Progress

The progress of individual students is monitored by their teachers, following school policies on assessment and following the national Assessment is for Learning guidance, which incorporates three main concept areas.

- Assessment *for* learning: supporting classroom learning and teaching
- Assessment *as* learning: learning how to learn
- Assessment *of* learning: gathering and interpreting the evidence.

Using these approaches, teachers make assessment judgments in all curriculum areas based on students' ongoing work in class and on class-based assessments. Progress for each individual student is reported to that student's parents.

National Assessments, which also are part of this strategy, are used by teachers to confirm their judgments of each student's progress in reading, writing, and mathematics. These assessments are based on the attainment targets set out in the curriculum guidelines for these subjects. National Assessments do not lead to certification but are a means of helping teachers ensure that their assessments are in line with nationally agreed upon standards. Schools only access the assessments when they have student(s) ready to be assessed. The assessment results for each student are reported individually to that student's parents. They also may be provided to any school to which a student subsequently transfers.³⁰

Grade Promotion and Retention Policies

Scotland does not have a policy of grade retention. Social cohesion is considered a key part of the educational process and therefore, all students move on within their age cohort, irrespective of academic progress. Where necessary, differentiation in teaching is provided to ensure that all students have opportunities to progress in their learning. In exceptional circumstances (e.g., as a result of a long illness), parents can request that their child repeat a grade.

Suggested Readings

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Serbia

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Introduction

Overview of Education System

Educational policy in Serbia is determined by the Ministry of Education. In 2001, the short-term goals of the ministry were to create a more efficient internal structure within the ministry and develop an educational reform strategy that could make schools more democratic bodies that foster a democratic education, use education to promote and achieve social and economic development, and match secondary vocational education and adult education to the needs of the Serbian labor market.

There are four levels of education in Serbia: preschool, primary, secondary, and tertiary education. There is a national curriculum at each level of education, which is adopted by the Ministry of Education, with the prior approval of the National Education Council, in accordance with the Law on the Education System Bases and the Law on the Amendments.²

Participation in preschool programs is optional in Serbia, except for the final year of preschool education, which is obligatory for all children, in accordance with the law.

Compulsory education in Serbia includes eight grades of primary school that typically are attended by students, ages 7 to 14. Primary education is divided into two stages: lower primary, grades 1 to 4 for ages 7 to 10, and upper primary, grades 5 to 8 for ages 11 to 14.

Secondary schooling in Serbia includes either 4 years of general education for students, ages 15 to 18 years, or 2, 3, or 4 years of vocational education for students beginning at age 15. Secondary education is provided in grammar schools (*gymnasia*), vocational schools, and art schools. Grammar schools offer general education in social studies and sciences. They also prepare students for further education, high school, or university faculties (tertiary education). By completing grammar school, students acquire four-form secondary education. Secondary vocational schools offer both general and vocational (practical and theoretical) education for direct entry into the world of work or further education. Specialized secondary schools (art schools) also provide 4 years of education in art, music, or ballet.

There also are special schools at the primary and secondary education levels. These schools are arranged for students with different forms of disabilities, such as physical and mental.

A key goal in Serbia today is to improve the educational outcomes for all children. Ensuring equality of opportunity, full participation, independent living, and economic self-sufficiency for all is an essential part of the national policy. The Serbian Plan of Action for Children,³ a strategic document of the government, is designed to help eliminate any kind of discrimination against children. The Ministry of Education plans special measures to support enrollment and reduce dropout rates. It also aims to increase the percentage of children from the Romany population and children with developmental difficulties completing primary education.

Language and Population

The Serbian language, using the Cyrillic alphabet, has been the principal language of instruction in all Serbia's state schools and other educational institutions, according to the Constitution of the Republic of Serbia. The use of the Latin alphabet in instruction also is permitted and some instructional materials may be published in this alphabet. According to the most recent national census in 2002, the country's population was 7.5 million (excluding the Kosovo Province). The majority of the population consists of Serbians (82.86%). In addition, there are other ethnic groups such as Hungarians (3.91%), Bosniaks (1.82%), the Romany population (1.44%), Yugoslavs (1.08%), and other ethnic groups (9.79%, each less than 1% of the population). Second-language education is provided at the preschool, primary, and secondary education levels in the regions with ethnic minorities, organized for children with a non-Serbian mother language. Other languages of instruction include Hungarian, Albanian, Slovak, and Romanian.

Emphasis on Mathematics and Science

The results from the previous TIMSS 2003⁴ assessment in Serbia are included in the process of finding appropriate solutions for improving general efficacy of the education system in Serbia. The Ministry of Education finds that these results can be very useful in the process of conceptualizing the strategy for education reform in Serbia. Several scientific and expert conferences have been held in Serbia that provided opportunities for discussing ways of changing the education system and analyzing the results of TIMSS 2003 achievement for Serbian eighth graders.

The Mathematics Curriculum in Primary and Lower Secondary Grades

Summary of National Curriculum Guides for Mathematics through Eighth Grade

The goal of mathematics education, defined in the mathematics curriculum for primary school in Serbia, are the following:^{5,6} students should acquire elementary mathematics knowledge necessary for understanding phenomena and causalities in society and everyday life, apply acquired mathematics knowledge in solving different tasks in the course of everyday life, and successfully continue mathematics education and self-education.

Mathematics instruction also should contribute to the development of students' mental abilities and the formation of scientific attitudes toward the world.

The objectives of mathematics instruction include the following: attainment of knowledge necessary for understanding quantitative and spatial relations and laws in different phenomena in nature, society, and everyday life; discovery of the role of mathematics and application in different areas of human activities (mathematical modeling), for continuing education and entering the work world; development of students' observation and thinking abilities, such as logical, critical, and creative and abstract thinking; development of mathematical curiosity in observing and exploring natural phenomena; development of students' use of mathematical language; formation of proper attitudes toward the world and the development of the person and his or her interpretation of mathematical subject matter and knowledge of basic mathematical methods; the acquisition of basic facts on sets, relations, and functions; the use of different sources of knowledge; mastering of basic operations with natural, rational and real numbers, and integers and also basic rules in using these operations; familiarization with two-dimensional geometric shapes and geometric solid figures, as well as with their mutual relations; development of students' accuracy in measuring, drawing, and geometric constructing; and enabling students to understand the appropriate content of the natural sciences and the contribution to technical education.

The mathematics curriculum for **lower grades 1–4** in Serbia is defined through educational outcomes. At the end of this level of mathematics education, students should be able to do the following: read and write natural numbers in the decimal system of numbers; know a set of natural numbers; know the units for area and apply them by calculating the area of a quadrangle, rectangle, and cube; read, write, and understand fractions; know and observe interdependence between outcomes and elements of operations; read and write basic properties of calculus operations by using letters; read, construct, and calculate outcomes of formulation with several operations; solve simple equations and inequations in a set of natural numbers; draw nets and models of cubes; apply acquainted properties of calculus operations in the process of transformation of task formulation and in cases of calculus easements; and solve tasks given in the text form.

The following is the list of outcomes for students at this level of mathematics education in two domains—"know" and "know how to".

- **Students should know** the order of natural numbers; properties of calculus operations; properties of "o" in operations of addition and multiplication and of "1" in the operation of multiplication; units of area; and formulas for the area of a quadrangle, rectangle, and cube.
- **Students should know how to** read, write, and compare natural numbers; accompany points of the numeral line to a series of natural numbers; read and compose formulations with several operations and calculate their results; make four basic calculus operations in a set of natural numbers; use acquainted properties of calculus operations in the calculating process for easier and faster calculation; observe interdependence between results and elements of calculus

operations; read and write fractions; solve equations and inequations of known forms; check independently the accuracy of performed calculus operations and the solution of an equation and an inequation; solve textual tasks (by composing formulation and equation); calculate the area of a quadrangle, rectangle, and cube; write correctly the solution of a task; and use a textbook.

The mathematics curriculum for **upper grades 5–8** also is defined through educational outcomes. At the end of this level of mathematical education, students should be able to do the following: understand basic properties of equality and inequality; understand mutual relations between points, lines, and planes in space; know how to solve linear equations and inequations and systems of linear equations with one of two unknown quantities on the basis of equivalent transformations and interpret solutions graphically; formulate mathematically and solve adequate textual tasks (especially by using equations); observe functional dependence in different fields and show them in different ways, especially to understand the more complete notion of a function and its graphics; enlarge and expand knowledge on functions, learning linear functions and their properties, be confident when drawing and reading different graphs of the functions; compose different tables and draw adequate graphs of different conditions, phenomena, and processes; know essential facts on geometric projections on an area; know geometric solid figures (prisms, pyramids, cones, cylinders, and balls), their elements, and their properties; draw nets and calculate the area and the volume of solid figures; apply elements of deductive reasoning; and apply knowledge to geometric solid figures in practice by connecting mathematics content and other fields of knowledge.

The Science Curriculum in Primary and Lower Secondary Grades

Summary of National Curriculum Guides for Science through Eighth Grade

In primary school in Serbia, the science curriculum is not integrated, and science (natural science) is presented through five separate science curricula: nature in grades 1–4, biology in grades 5–8, geography in grades 5–8, physics in grades 6–8, and chemistry in grades 7–8.

In the **nature** curriculum for the fourth grade of primary school,^{7,8} the goals of education are defined in the following way: development of basic notions on natural and social environment and connections between these concepts; development of abilities to perceive basic characteristics of objects, phenomena, and processes in the environment and understanding their connectedness; development of the basic elements of logical thinking; development of curiosity, interests, and active exploration of the environment; development of ecological awareness and habits of healthy living; integration of empiric and scientific knowledge into the frameworks of the system of concepts; attainment of elements of scientific literacy and the formation of the foundation for further learning; orientation in space and time; and qualifying students for learning and finding information.

The basic intention of nature instruction is not only the acquisition of program content but also initializing students' developmental potential. The process of instruction is targeted at the development of students' intellectual, psychophysical, cognitive, affective, and social spheres, which are set through the established educational objectives in this domain.

The **biology** curriculum is structured for grades 5 to 8.^{9,10} The general educational goals of biology instruction in primary school in Serbia are defined in the following way: students should acquire, through the development of basic concepts, knowledge on the evolutionary development of the living world and laws that determine it. The goals of biology instruction also include developing adequate qualities and habits, observations, abilities of critical thinking, objectivity, logical reasoning, attitudes towards nature and necessities for protecting nature and the environment, and adequate hygiene habits and habits of healthy living.

In the biology curriculum, the educational objectives of what students are able to do are defined in the following way: understand the role and importance of biology for the development and progress of mankind; understand mutual relations between living beings and the environment and also the dynamics of subject matter transformations in nature and the flow of energy; understand the level of endangerment in the biosphere and the role of each individual in its protection and improvement; understand gradation in the development of the living world and the genesis of the Earth and life on the Earth; develop awareness of one's own position in nature; develop the ability to connect concepts on processes occurring in living beings and in nature; develop sensitivity of one's responsibility for the status of the environment; attain knowledge on diversity and the dispersion of organisms; and know the structure and functions of their own organism and acquire adequate hygiene habits and responsibility for their own health and the health of other people.

The **geography** curriculum also is structured for grades 5 to 8.^{11,12} Geographical knowledge is considered an important component of each individual's general culture. Geography instruction has several educational goals. Through acquisition of geographical knowledge and the use of basic objects, students should be familiar with the phenomena and processes in space, their causal connections and relations, and upon this knowledge, they should build their own geographical thinking about their homeland, state, continent, and the whole world. Geography instruction should enable students to use geographical maps, work in the field of exploration, and find out and analyze sources of geographical information independently. Through acquired knowledge, students should develop awareness of the importance of protecting each geosphere, as the ecological framework for living on the Earth, and form responsible attitudes towards the environment. The role of geography instruction also is to develop tolerance to different nations, their cultures, and ways of living.

In the geography curriculum, the educational objectives in instruction are defined in the following way: know and understand phenomena and processes in the geographical shell of the Earth and in the surroundings of the shell; know basic geographical features of Europe, its regions and states, other continents, and the economically developed states in the world; develop cartographical literacy and the ability to use geographical maps in everyday life; develop geographical thinking based on connectivity and mutual conditionality of geographical phenomena and processes in space and time; develop attitudes on prevention, protection, and improvement of the environment; develop a national, European, and global identity; develop tolerance, existence, and belonging to the multi-ethnic, multilingual, and multicultural world; and develop the general culture in students.

In the **physics** curriculum for grades 6 to 8 in Serbia,^{13,14} general educational goals are defined as follows: know natural phenomena and basic natural laws, acquire basic scientific literacy, explore and recognize physical phenomena in everyday life and actively acquire knowledge on physical phenomena through exploration, develop the basis of knowledge of the scientific method, and orient students towards the application of physical laws.

In the physics curriculum, the educational objectives in instruction are defined in the following way: development of functional literacy; development of the abilities to actively acquire knowledge on physical phenomena through exploration; development of curiosity, rational reasoning, independence in thinking, and clear and precise expression skills; development of logical and abstract thinking; development of abilities to apply knowledge in the field of physics; development of the tendency towards studying the science of nature; development of the awareness of one's own knowledge, abilities, and further professional orientation; understand phenomena, processes, and relations in nature based on physical laws; understand the meaning and method of conducting an experiment and the role of measuring; understand the interconnections between physical phenomena and ecology, as well as the development of awareness of the necessity for protection, renewal, and improving the environment; understand the basic ways of thinking and reasoning in physics; and understand how to solve simple problems and tasks within the framework of the teaching content.

In the **chemistry** curriculum for grades 7 to 8,¹⁵ the goals of chemistry instruction are defined in the following way: development of functional literacy in the field of chemistry; development of communication abilities by using chemical terms, symbols, formulas, and equations; development of abilities to solve theoretical and experimental problems; development of logical and abstract thinking abilities and a critical attitude in thinking; development of abilities to search and use relevant information from different sources (textbook, scientific and popular articles, and the Internet); development of the importance of having a responsible attitude towards the environment and the adequate and rational use and disposal of different materials in everyday life; development of curiosity, the necessity for knowledge attainment on properties of substances in the environment, and a positive attitude towards studying chemistry; development of one's

own knowledge, abilities, and further professional orientation; and understanding of changes and phenomena in nature on the basis of acquiring chemical concepts, theories, models, and laws.

The educational objectives of chemistry instruction are defined in the following way: understand the subject matter of chemistry study and the scientific method; perceive the importance of chemistry in everyday life for development of different technologies and society in general; conduct simple investigations; understand the quantitative aspects of chemical changes and their practical applications; create and conduct demonstration experiments and develop analytic thinking and critical thinking in these situations; develop experimental skills properly and safely and handle laboratory equipment and substances; apply theoretical knowledge and the experimental experience in solving theoretical and experimental problems; apply chemistry knowledge for interpretation of phenomena and changes in the environment; use the language of chemistry, know chemical terminology, and understand both the qualitative and quantitative meaning of chemical symbols, formulas, and equations.

Instruction for Mathematics and Science in Primary and Lower Secondary Grades

Instructional Time

Mathematics instruction in the lower grades (1–4) of primary school in Serbia is 5 hours per week. In the upper grades (5–8), mathematics instruction is 4 hours weekly. Mathematics accounts for 20 percent of total instructional time for the lower and upper grades. Science instruction, realized through the program of nature, occurs 2 hours per week (i.e., 10% of total instructional time for the lower grades). Science instruction in the upper grades is realized as follows: biology, grades 5–8, 2 hours weekly; geography, 1 hour in grade 5 or 2 hours weekly in grades 6–8; physics, grades 6–8, 2 hours weekly per grade; and chemistry, grades 7–8, 2 hours weekly per grade. Science instruction in the upper grades is represented by the following percent of instructional time: 11 percent in the fifth grade, 20 percent in the sixth grade, 27 percent in the seventh grade, and 27 percent in the eighth grade.

Instructional Materials, Equipment, and Laboratories

Prior to 2000, educational equipment was in short supply, and teaching materials sometimes were provided by international organizations, such as UNICEF, rather than by the state due to Serbia's severe economic problems and the economic embargo on the country. From 2001 to the present, the Ministry of Education has made a great effort to supply schools with computer hardware and software, instructional materials, equipment, and laboratories. Progress in this domain is obvious and significant.

Grade at Which Specialist Teachers for Mathematics and Science Are Introduced

Students in the lower grades (1–4) have one teacher for all subjects called the teacher of class instruction. The only exception is in the fourth grade, where students have teachers for art and physical education, but it is only an option and not a rule, and it depends on

each school's opportunity to employ separate teachers for these two subjects. Teachers in the lower grades are required to be faculty educated, according to the current law,¹⁶ but they do not have specialization in mathematics and science at this level of schooling. Students in upper grades (5–8) have particular teachers for each subject who are specialists in subject areas, including mathematics and the sciences (biology, geography, physics, and chemistry).

Use of Technology

In accordance with the efforts of the Ministry of Education to supply schools with computers and other multimedia equipment, the goal of schools is to use computers and multimedia in mathematics and science teaching. However, computers are mostly used outside of teaching, mainly in extra-work activities in mathematics and science. The curriculum for mathematics and science does not prescribe or explain ways of using computers in mathematics and science teaching.

Homework Policies

There is no homework policy defined within the framework of the mathematics and science curriculum, and it is up to mathematics and science teachers when, how, and to what extent they assign homework. Despite this fact, homework is assigned relatively often, on the basis of teachers' attitudes towards the basic role of homework. Homework is a successful tool for improving student knowledge and the conceptual base in the fields of mathematics and science, especially in the areas of physics and chemistry, since these subjects are considered difficult by both primary and secondary school students in Serbia.

Teachers and Teacher Education

Preschool teachers receive 3 years of tertiary education level training either in specialized teacher preparation schools or at university faculties. Lower primary grade teachers attend teacher training colleges (teachers' training faculty) for 4 years, and upper primary grade teachers also complete 4 years of tertiary education (different faculties), covering the relevant disciplines in which they will teach. Primary teachers of music and art education receive training in art high schools (for both music and the arts) that offer specialized training. Secondary education level teachers receive 4 years of higher education at arts and science faculties with special courses in education and teaching methodology integrated with their studies.

Teacher Professional Development in Mathematics, Science, and Technology

During 1990–2000, the Ministry of Education offered one or two seminars and workshops per year to teachers as refresher courses in specific subject areas. Besides these activities, there were some opportunities for teachers in the domain of professional development, such as completing a higher level of education in the field of teaching, completing some scientific degree level, etc. At the present time, there is an established system of teacher professional development, supported and monitored by the government institution, the

Institute for Education Improvement. This system of different seminars and workshops includes teachers of preschool, primary school, and secondary school levels. This represents the main way that mathematics and science teachers receive professional development in Serbia.

Examinations and Assessments

National or Regional Examinations

A final examination is not given at the end of primary education in Serbia. However, there is a Qualification Examination, which students take just after completing primary school. This examination tests knowledge in the Serbian language (or the mother tongue, for national minorities) and in mathematics. The Matura examination is one of the national-level examinations in secondary education in the Republic of Serbia.

As a result of the Law on the Education System Bases and the Law on the Amendments, the Institute for Education Quality and Evaluation was established in 2003. The general purpose of this institution is to organize and conduct different kinds of assessments in the domain of education, including at the primary and secondary levels of education. The national testing of student achievement was performed in the third grade of primary school in 2003 and in the fourth grade of primary school in 2006.

Monitoring Individual Student Progress

Teachers monitor and evaluate student progress through several forms of assessment, such as oral questioning, testing, using quizzes, group work assessment, etc. Similar forms of assessment are used in both lower and upper grades of secondary school. The criteria for assessing student achievement levels include: type, depth and level of knowledge, skills, and competencies acquired, as compared to those envisioned by the curriculum and syllabus for a given school subject, grade, educational profile, or type of school. The main focus of legal documents and practice in schools is on summative assessment. Assessment results are expressed using the system of numerical marks: 1, failed (insufficient); 2, sufficient; 3, good; 4, very good; and 5, excellent. Descriptive marking was introduced in the first grade of primary school in 2003 for the first time.

Grade Promotion and Retention Policies

Grade-to-grade promotion of students in the lower grades and upper grades is usually automatic, especially in the lower grades. It is not an obligatory form of promotion but is optional, based on the teacher's appraisal of the student's real progress. Students who at the end of instructional time (the end of June) have more than two insufficient marks and those with one insufficient mark at the end of the school year (the end of August) may not be promoted to the next grade.

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Singapore

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Introduction

Overview of Education System

As a city state with a small population, education has always been a top priority for Singapore. The Ministry of Education¹ directs the formulation and implementation of education policies, and controls the development and administration of publicly funded schools, which cater to virtually all Singaporean students. Singapore's education system also is characterized by a centralized curriculum whereby syllabi for various subjects and assessment guidelines are provided by the ministry. The ministry also is responsible for Singapore's national examinations through its statutory board, the Singapore Examinations and Assessment Board.²

The ministry's mission is to mold the future of the nation, by molding the people who will determine the future of Singapore. The education system of Singapore provides all children with a holistic education, develops them to their full potential, and nurtures them into good citizens, conscious of their responsibilities to family, society, and country. Schools focus on the cognitive development of students, as well as on building and developing their social skills and character through cocurricular activities and enrichment programs. The ministry's vision is to have a nation of thinking and committed citizens capable of meeting the challenges of the future and an education system that is geared to the needs of the 21st century. Since 2004, the education system has moved toward more quality in terms of classroom interaction, opportunities for expression, and the learning of lifelong skills through innovative and effective teaching approaches, and away from quantity in terms of rote learning, repetitive tests, and following prescribed answers and set formulae. It also reaffirms the learner at the center of all that is being done and better recognizes and caters to the various needs and interests of different learners.

As a further refinement to the delivery of an ability-based, aspirations-driven education system, new education pathways and curricular options have been introduced in recent years. These recognize the different abilities, learning styles, and interests of students and give them flexibility to progress along the most suitable education pathways where they can be stretched to their fullest potential. Much of this enhancement in flexibility and choice is achieved through innovations at the school level, with school leaders and teachers taking the initiative to develop their own school-based programs to meet the learning needs of their students. To encourage schools to embark on such innovations, the ministry provides top-down support to help these ground-up initiatives succeed.

Students receive 6 years of primary education and 4 to 5 years of secondary education, followed by at least 2 years of postsecondary education at the junior colleges/centralized institute, polytechnics, and the Institute of Technical Education. The different education pathways of Singapore's education system are shown in Exhibit 1.

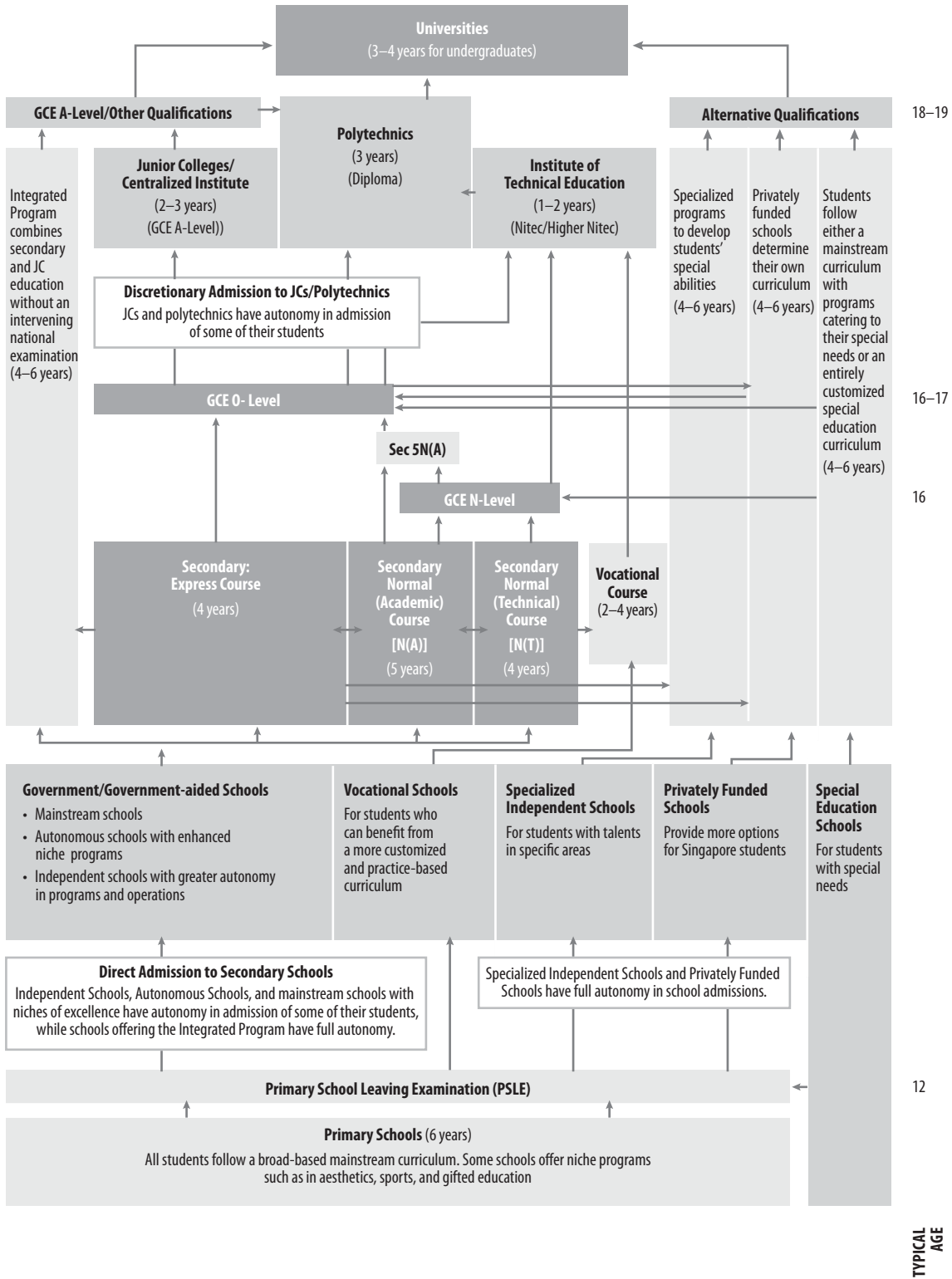
In 2003, Singapore implemented the Compulsory Education Act for primary school students. The 6-year compulsory education aims to give all children a common core of knowledge that will provide a strong foundation for further education and a common educational experience that will help to build a strong national identity and social cohesion.

Preschool education in Singapore aims to meet the distinct development needs of the child in his or her early years. It helps the child develop socially, emotionally, and physically, while also teaching literacy and numeracy skills in preparation for primary education. Various community and private organizations provide a range of preschool education programs, including half-day kindergartens and centers that provide full-day childcare options.

Primary education consists of a 4-year foundation stage (primary 1 to 4) and a 2-year orientation stage (primary 5 and 6). At the foundation stage, all students follow a common curriculum that provides them with a firm foundation in all the domains of education. From primary 1 to primary 4, the curriculum emphasizes basic literacy and numeracy skills, and the core subjects are English, the mother-tongue language, and mathematics. Science is introduced from primary 3 onward. The other subjects that are taught in primary school are civics and moral education, social studies, health education, physical education, art, and music.

Streaming, which has been a key feature of Singapore's education system, allows children to learn and progress at a pace that they are comfortable with. Over the years, the ministry has made various refinements to its streaming policies to better customize the learning experience for students of varying abilities and to help them discover and develop their strengths.

Exhibit 1 Structure of the Education System in Singapore



SOURCE: Ministry of Education, Singapore. (2008)

Prior to 2008, schools would assess student performance at primary 4 and advise parents on the appropriate stream for their children. Parents retained the option to enroll their children in either the merged stream (EM1/2) or EM3 stream in primary 5.

Students in the merged stream took English, mathematics, science, and the mother-tongue language at the standard level. Students also could opt to take the mother-tongue language at a higher proficiency level. The EM3 stream was customized for students who were weaker in the languages, mathematics, and science and allowed them to learn these subjects at the foundation level. In the past few years, about 7 percent of each cohort was recommended for the EM3 stream.

Beginning with the 2008 primary 5 cohort, subject-based banding replaced the EM1/2 and EM3 streams. In line with the philosophy of an ability-based education system, students are given the flexibility to take a mix of standard or foundation level subjects, depending on their aptitude in each subject. For example, a student who is strong in English but weak in mathematics could take English at the standard level and mathematics at the foundation level.

At the end of primary 6, all students sit for the Primary School Leaving Examination (PSLE), which assesses their abilities for placement in a secondary school course that suits their learning pace and aptitude. Subjects included in the examination are mathematics, science, English language, and the mother-tongue language. Based on their results on this examination, students are admitted to the express, normal (academic) or normal (technical) course in secondary school. Currently, about 60 percent of students are admitted into the express course, about 25 percent into the normal (academic) course, and around 15 percent into the normal (technical) course.

At the **secondary** level, students in the express course follow a 4-year program leading to the Singapore-Cambridge General Certificate of Education (GCE) O-level examinations. The normal (academic) course caters to students who need a longer time to benefit from the O-level curriculum. Students in the normal (academic) course follow a 4-year program leading to the GCE N-level examinations. Those who performed well at the N-level examinations can proceed to secondary 5 and sit for the O-level examinations at the end of the fifth year. The normal (technical) course prepares students for articulation into technical education at the Institute of Technical Education after a 4-year program leading to the GCE N-level examinations. The system provides for lateral transfers between courses to enable students to progress at a pace that is most suited to their abilities. For example, a normal (technical) student who has performed well could transfer laterally to the normal (academic) course. Likewise, a normal (academic) student could transfer to the express course if he has performed well.

In recent years, changes have been introduced in the secondary school curriculum to stretch the potential of students and provide more opportunities for them to pursue their interests to the fullest. Students are given more choice in the range of subjects they could take, based on their interest and ability. Selected secondary schools may offer new GCE O-level subjects, such as economics, drama, and computer studies to their students. Students in the normal (academic) and normal (technical) courses may take elective modules³ and those with the ability also can take subjects at a higher proficiency level. Schools also have been given the flexibility to allow selected students in the normal

(academic) course to bypass the N-level examinations and progress directly to the O-level examinations at the end of secondary 5.

The Integrated Program, providing a seamless secondary and junior college education experience without the GCE O-level examinations, has been implemented in selected schools since 2004. The program gives students in the top 10 percent of each cohort more flexibility to engage in broader learning experiences that will develop their leadership, and capacities for creative and critical thinking.

Students who are talented in sports, arts, or mathematics and science can further develop their talents with the customized curriculum provided by specialized independent schools. The Singapore Sports School was established in 2004 and the School of the Arts opened in 2008. The National University of Singapore (NUS) High School of Mathematics and Science started in 2005 and provides a 6-year education. Students can study NUS undergraduate modules at the NUS high school and receive mentoring by NUS faculty members. Besides graduating with the NUS high school diploma, students also will sit for the Scholastic Assessment Test and Advanced Placement tests.

Since 2005, three privately funded schools have been established. These schools provide a source of innovation in curriculum and alternative qualifications and are allowed to admit foreign students, subject to a cap of 50 percent of total student enrollment. They are also required to adhere to the ministry's bilingual and national education policies for Singaporean students.

At the end of 10 or 11 years of general education, all students have viable options for postsecondary education and training over a wide range of courses. About 30 percent, 40 percent, and 20 percent of Singaporean students in every cohort are admitted into junior colleges/centralized institute, polytechnics, and the Institute of Technical Education, respectively. Students who are more academically inclined, and have the necessary GCE O-level qualifications, can opt for pre-university courses in academic subjects at the junior colleges/centralized institute. These students take the GCE A-level examinations at the end of 2 years for junior colleges or 3 years for the centralized institute, and those who qualify, progress to the universities. Students also can opt for diploma courses in technical and business subjects at the polytechnics. In addition to the 15 percent of polytechnic graduates who qualify and enroll in the local universities, many polytechnic students go on to obtain their undergraduate degrees in overseas universities. Students with GCE O-level or N-level certificates are eligible for skills-based certificate courses in technical and vocational subjects offered by the Institute of Technical Education. Outstanding Institute of Technical Education graduates could proceed to the polytechnics and eventually to the universities.

About 25 percent of each cohort of Singaporeans will progress to the local universities. To allow more students to pursue tertiary education, the ministry plans to increase the number of publicly funded university places to 30 percent of each cohort from 2015, by establishing a fourth publicly funded university to complement the existing universities (National University of Singapore, Nanyang Technological University, and Singapore Management University).

Language and Population

Singapore has a multi-ethnic population with a diverse language environment. There are four official languages: Malay, Chinese (Mandarin), Tamil, and English. Malay is the national language, while English is the language of administration and the common language spoken by Singaporeans. The proportion of the resident population ages 15 years and over who are literate increased from 92.5 percent in 2000 to 95.4 percent in 2006.⁴ Between 2000 and 2005, there also was an increase in the use of English as the predominant home language among all the major ethnic groups.⁵ A cornerstone of Singapore's education system is the bilingual policy that allows each student to learn English and his or her mother tongue, which could be Malay, Chinese, or Tamil, to the best of his or her ability. This enables students to be proficient in English, which is the language of commerce, technology, and administration and their mother tongue, the language of their cultural heritage.

Emphasis on Mathematics and Science

There is great emphasis on the teaching and learning of mathematics and science in Singapore. At the primary and secondary levels, mathematics and science are core subjects that every student must take. Mathematics education begins when a student enters the formal school system at primary 1, while science is taught formally from primary 3 onward. Although science is not included in the primary 1 and 2 curricula, it is taught and learned indirectly through language and other activities. From the upper primary levels onward, students will have specialist teachers in mathematics and science. At the upper secondary level, students with the inclination and interest have the opportunity to learn deeper mathematics concepts by taking additional mathematics (a different subject than mathematics), which will prepare them well for mathematics courses at higher educational levels. At the pre-university level, students are required to take at least one subject in mathematics or science at the higher 1 (H1)⁶ or higher 2 (H2) levels. In addition, students who have special strengths in mathematics and science can pursue these subjects beyond the regular curricula, by studying them at the higher 3 (H3)⁷ level.

Cocurricular activities such as mathematics and science fairs, competitions, and learning trails (where students apply mathematics and science concepts in outdoor settings) are used to generate interest in the subjects among students. Centers of Excellence in Mathematics and Science, pooling together resources from various schools at cluster⁸ and zonal⁹ levels, also have been established to provide students with opportunities to enrich their learning experience. At the national level, the DNA Learning Laboratory at the Science Centre and the DNA Centre at the National Institute of Education focus on the teaching and learning of life sciences through hands-on activities for primary and secondary school students, and the training of preservice and inservice teachers. To foster an interest in science, the ministry works closely with the Agency for Science, Technology and Research (A*STAR)¹⁰ and the Science Centre¹¹ to provide opportunities for students to be exposed to research and development under the guidance of scientists and researchers from the various institutes of higher learning and research institutes.

Overarching Policies Related to Education and the Curriculum for Mathematics and Science

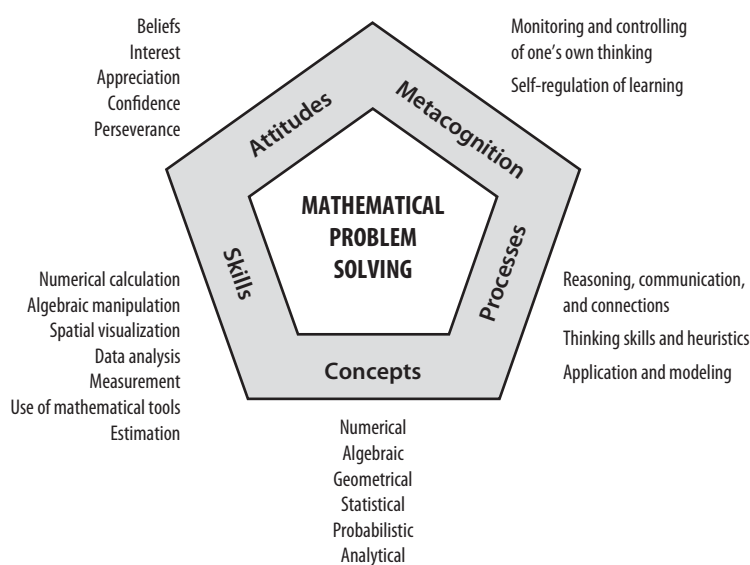
As a technology-based economy, Singapore always has focused strongly on science, technology, engineering, and mathematics. This emphasis on mathematics and science has allowed Singapore to harness technology and rational policy-making to overcome its constraints as a small open economy with scarce resources. Singapore's education system provides students with a strong foundation in mathematics and science and allows them to pursue and further develop their talents through various programs. This focus is reinforced at the tertiary level, as more than half of the programs are oriented toward science and technology. As a result, Singapore has achieved success in expanding research and development capabilities and leveraged innovation as a new engine of growth. There is significant investment by global companies in research and development in Singapore's industry sectors like electronics, chemicals, biomedical sciences, and info-communications.

The Mathematics Curriculum in Primary and Lower Secondary Grades

Summary of National Curriculum Guides for Mathematics Through Eighth Grade

A single curriculum framework is used consistently throughout the different levels, differing only in the details at each level but sharing common emphases throughout the levels. The Singapore mathematics curriculum is characterized by the Mathematics Curriculum Framework¹² (see Exhibit 2), which aims to develop students' mathematical abilities, with a focus on problem-solving ability. Five interrelated components, namely concepts, skills, processes, metacognition, and attitudes, support the development of problem-solving abilities. The framework sets out directions for the teaching, learning, and assessment of mathematics.

Exhibit 2 Singapore Mathematics Curriculum Framework



The following exhibit presents a summary of the concepts and skills to be covered by the **end of secondary 2**.

Exhibit 3 Singapore Mathematics Concepts and Skills

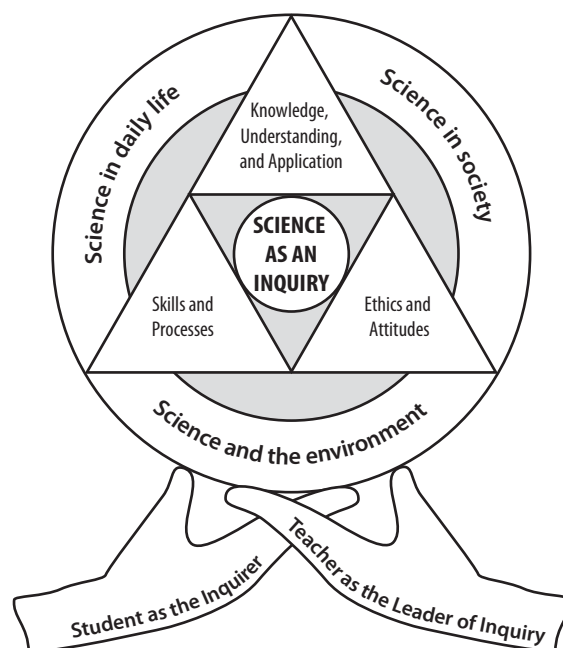
Primary Mathematics	Lower Secondary Mathematics
Numbers and Algebra	
Whole numbers, fractions, and decimals and the four operations Calculation with calculators Factors and multiples Ordering of numbers Approximation and estimation Percentage Ratio Speed Algebraic expressions in one variable	Negative numbers, integers, rational numbers and real numbers, and the four operations Calculation with calculators Prime numbers, HCF, and LCM Ordering of numbers Use of symbols: $<$, $>$, \leq , \geq Approximation and estimation Percentage Ratio, direct and inverse proportion Map scales Rate and speed Algebraic expressions and formulae Algebraic manipulation (linear and quadratic) Functions and graphs (linear and quadratic) Linear equations with one unknown Simultaneous linear equations with two unknowns Quadratic equations Linear inequalities with one unknown Set language and notation
Geometry and Measurement	
Measurement of length, mass, volume, time, and angle Area and perimeter of triangles, circles, and volume of cubes and cuboids Properties of simple geometric figures Nets of simple solids Line symmetry Ideas of tessellation	Properties and construction of simple geometric figures Angles associated with parallel lines Angles of polygons Congruence and similarity Area of plane figures, volume, and surface areas of 3-D solids Pythagorean theorem
Statistics and Probability	
Picture graphs, bar graphs, tables, line graphs, and pie charts (including interpretation and use of information to solve problems) Average	Data handling (including data collection and representation) Data analysis (including interpretation and analysis of various statistical representations) Probability

The Science Curriculum in Primary and Lower Secondary Grades

Summary of National Curriculum Guides for Science Through Eighth Grade

Central to the Singapore Science Curriculum Framework¹³ (see Exhibit 4) is the planned inculcation of the spirit of scientific inquiry. Inquiry is founded on three integral domains essential to the practice of science: knowledge, understanding, and application; skills and processes; and ethics and attitudes. The curriculum design seeks to enable students to view the pursuit of science as meaningful and useful. Inquiry is thus grounded in knowledge, issues, and questions that relate to the roles played by science in daily life, society, and the environment.

Exhibit 4 Singapore Science Curriculum Framework



SOURCE: Curriculum Planning and Development Division, Ministry of Education, Singapore. (2004)

The primary and lower secondary science syllabi are designed based on themes that students can relate to in their everyday experiences, and on commonly observed phenomena in nature. The five themes at the primary level are: diversity, cycles, energy, interactions, and systems. At the lower secondary level, the first four themes are similar to those found in primary science. The themes models and systems and measurement are introduced only at lower secondary. The following (Exhibit 5) presents a summary of the topics to be covered under each theme by the **end of secondary 2**.

Exhibit 5 Singapore Science Concepts and Skills

Primary Science	Lower Secondary Science
Diversity	
Variety and characteristics of living things Materials Classification of organisms and materials	Classification of matter Classification of plant and animal life Elements, compounds, and mixtures Solutions and suspensions
Cycles	
Life cycles of plants and animals Matter Water Day and night cycles Unit of life Reproduction in plants and animals	Nutrient cycles in the ecosystems
Energy	
Light Heat Photosynthesis and respiration Forms of energy and conversions	Sources and storage of energy Photosynthesis and respiration Light Electricity
Interactions	
Magnets Simple machines Forces Environmental impact Ecology	Force and its related concepts Effects of heat Transmission of heat Chemical changes Sound Simple concepts of populations, community, and ecosystem Energy transfer process in the ecosystem Abuses to life processes
Systems	Models and Systems
Plant parts and functions Digestive and skeletal / muscular systems Respiratory and circulatory systems Electrical systems	Cells—structure, function, and organization Particulate model of matter Simple concepts of atoms and molecules Transport in living organisms Digestion in animals Sexual reproduction in human beings
	Measurement
	Use of measuring instruments Physical quantities and units

Instruction for Mathematics and Science in Primary and Lower Secondary Grades

Instructional Time

The weekly instructional time for mathematics and science at the various levels is presented in Exhibit 6 below. The hours per week for each subject is a guideline. Schools may vary this slightly according to the needs of the students.

Exhibit 6 Weekly Instructional Time in Singapore

Level	Mathematics		Science	
	Hours per Week	% of Total Instructional Time	Hours per Week	% of Total Instructional Time
Primary 1	3.5	15	–	–
Primary 2	4.5	19	–	–
Primary 3	5.5	22	1.5	6
Primary 4	5.5	22	2.0	8
Primary 5 and 6	5.0–6.5	20–27	1.5–2.5	6–10
Secondary 1 and 2: Express and Normal (Academic)	3.0–3.5	12.5–15	3.0–3.5	12.5–15
Secondary 1 and 2: Normal (Technical)	5.0	20	2.5	10

Instructional Materials, Equipment, and Laboratories

Following the approval of new or revised syllabi in mathematics and science, commercial publishers are invited to develop and publish textbooks and related materials such as activity books or workbooks for use in primary and secondary schools. These materials undergo a stringent review and authorization process by the ministry, and must meet the quality standards and requirements of the relevant syllabi before they are approved and placed on the online Approved Textbook List.¹⁴

Schools are well resourced with funds to purchase various teaching aids and manipulatives for supporting the teaching and learning of mathematics. These resources may be centrally stored within a school's mathematics room, which also serves as a focal point for mathematics activities and innovation, or they may be stored and made available within each classroom.

Schools are also well equipped with the necessary laboratory equipment and resources to enhance their ability to deliver the science syllabi. Primary and secondary schools are provided with science rooms and laboratories, respectively. Teachers may use these special rooms or laboratories to conduct activity-based lessons, scientific investigations, and demonstrations and to facilitate group work and investigative projects.

Use of Technology

Schools are equipped and supported through the ministry's Masterplan for Information and Communications Technology¹⁵ (ICT) in Education 1 (1997–2002) and 2 (2003–2008), to enhance the teaching and learning of mathematics and science. The Masterplan for

ICT in Education 1 was a blueprint for the use of ICT in schools and access to an ICT-enriched school environment for every child. The Masterplan for ICT in Education 2 consolidates and builds on the achievements of the first masterplan, and continues to provide the overall direction on how schools can harness the possibilities offered by ICT for teaching and learning.

At the primary level, from primary 1 to 4, students' foundation in basic numeracy skills, including mental computation and estimation, is built up. Starting from the 2008 primary 5 cohort, calculators have been introduced into primary mathematics to enhance the teaching and learning process, and allow students more time to focus on problem solving instead of routine computations. At the secondary level, one of the objectives of the mathematics curriculum is to enable students to make effective use of a variety of mathematical tools, including the calculator, in the learning and application of mathematics.

Teachers and Teacher Education

Education and Training for Fourth and Eighth Grade Mathematics and Science Teachers

The Ministry of Education recruits teachers from the top one third of each cohort through a stringent selection process. Teachers are mainly recruited from university graduates, as well as from the A-level graduate pool and academically stronger polytechnic graduates. Mathematics and science teachers in the secondary schools and in junior colleges/centralized institute are required to be university graduates in the relevant subject disciplines.

All beginning teachers are required to undergo preservice professional training conducted by the National Institute of Education¹⁶ (NIE), an institute of the Nanyang Technological University. The 2-year Diploma in Education programs train GCE A-level or polytechnic graduates to teach at the primary level. The 4-year degree programs with a Diploma in Education train GCE A-level graduates or polytechnic graduates, and the 1- or 2-year Postgraduate Diploma in Education programs train university graduates to teach at either the primary or secondary level. Generally, primary level teachers are trained to teach various subjects including English, mathematics, and science, while secondary level teachers specialize in teaching at most, two subjects. Students have specialist teachers in mathematics and science from the upper primary levels onward.

The programs at the NIE provide relevant pedagogical and instructional training in various subjects including mathematics and science. A core component of every initial teacher preparation program is the practicum in school, where student teachers are guided by their cooperating teachers and NIE supervisors through systematic observations, assistance, and advice. They participate actively in all aspects of a school's activities, and acquire the understanding and necessary skills for teaching effectively in a range of classroom situations.

Teacher Professional Development in Mathematics, Science, and Technology

The Ministry of Education places great emphasis on teacher development and recognition, and is committed to ensuring that the teaching profession remains current in terms of skills and knowledge and is well positioned for the future.

All teachers are entitled to 100 hours of professional and personal development training per year. The NIE works closely with the ministry to provide training courses and advanced programs, including the Advanced Diploma, Advanced Postgraduate Diploma, master's degree, and Doctor of Philosophy degree. The ministry also provides specialized professional development courses to upgrade the content knowledge of teachers, and to update teachers on pedagogical innovations and new assessment modes in the teaching of mathematics and science.

Other than formal professional development courses, teachers can also benefit from experiential learning in the business and community sectors through the Teacher Work Attachment scheme, which started in 2003. Through these local or overseas work attachments, teachers gain new experiences that, in turn, benefit students by way of the fresh perspectives they bring back to their classrooms.

Examinations and Assessments

National or Regional Examinations

The Singapore Examinations and Assessment Board, in collaboration with the Ministry of Education, conducts national examinations in Singapore, including the PSLE, GCE N-level, GCE O-level, and GCE A-level examinations.

Monitoring Individual Student Progress

Students are assessed both formally and informally in schools. At every level, schools generally conduct at least two summative examinations, one at the end of each semester. These assessments tend to adhere closely to the approach and format adopted in the national examinations. For formative assessments, teachers adopt different modes ranging from pen-and-paper tasks, such as written tests and worksheets, to oral presentations and portfolios. Formative assessments provide useful indicators for teachers to monitor their students' progress, identify their strengths and weaknesses, and provide meaningful and immediate feedback. They also enable teachers to modify their teaching methods and materials to suit the needs and abilities of their students.

Schools monitor closely the progress of each student. Records of students' performance are kept through the student dossier and in report cards or report books. Students regularly take work home and parents are advised regularly of their children's performance through progress reports (e.g., report cards), personal calls, home visits by teachers, and school-organized parent-teacher meetings.

Grade Promotion and Retention Policies

In primary schools, retention is generally not practiced from primary 1 to 4. A student in primary 5 may be considered for retention if, in the opinion and professional judgment of the principal, such retention is beneficial for the student. At primary 6, all students will

take the PSLE, which assesses their suitability for secondary education and places them in an appropriate secondary school course. In secondary schools and junior colleges/centralized institute, promotion to the next level is dependent on academic progress and performance in school assessments.

References

- 1 Ministry of Education, Singapore: <http://www.moe.gov.sg>
- 2 Singapore Examinations and Assessment Board: <http://www.seab.gov.sg>
- 3 Elective modules are optional modules, typically 20–30 hours, to develop students' interests and strengths in specific areas, such as digital animation, motorcycle maintenance, and nursing.
- 4 Department of Statistics, Ministry of Trade & Industry. (2007). *Singapore 2007 statistical highlights* (p. 60). Singapore: Author. Retrieved October 3, 2007, from <http://www.singstat.gov.sg/pubn/catalogue.html>
- 5 Department of Statistics, Ministry of Trade & Industry. (2006). *General household survey 2005, statistical release 1: Socio-demographic and economic characteristics* (p. 17). Singapore: Author. Retrieved October 3, 2007, from <http://www.singstat.gov.sg/pubn/popn/ghsr1.html>
- 6 In 2006, MOE introduced the new A-level curriculum which offers subjects at the H1, H2 and H3 levels in increasing order of rigor. A subject at the H2 level is equivalent in rigor to the previous A-level. A subject at the H1 level is equivalent to half the content of the subject at the H2 level.
- 7 Subjects at the H3 level take the form of an independent in-depth research essay, undergraduate modules, or new MOE-developed curricular units.
- 8 A school cluster system is made up of 12 to 14 schools in close geographical proximity and is overseen by the Cluster Superintendent, an experienced school leader.
- 9 School clusters are grouped into 4 main geographical zones, namely north, south, east, and west zones.
- 10 Agency for Science, Technology, and Research: <http://www.a-star.edu.sg/astar/home.do>
- 11 Science Centre Singapore: <http://www.science.edu.sg/ssc/index.jsp>
- 12 Ministry of Education, Singapore. (2007, September 24). *Subject syllabuses*. Retrieved October 3, 2007, from <http://www.moe.gov.sg/cpdd/syllabuses.htm>
- 13 Ibid.
- 14 Ministry of Education, Singapore. (2007). *Approved textbook list*. Retrieved October 3, 2007, from http://nsinte1.moe.edu.sg/project/db/atl/db_puatl.nsf
- 15 Ministry of Education, Singapore. (2006, November 30). *Overview of the masterplan II for ICT in education*. Retrieved October 3, 2007, from <http://www.moe.gov.sg/edumall/mp2/mp2.htm>
- 16 National Institute of Education: <http://www.nie.edu.sg>



The Slovak Republic

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Introduction

Overview of Education System

As of January 2004, a new act has regulated state administration and self-government in primary and secondary schools and school facilities. The Ministry of Education oversees the state administration of the school system. The ministry also is responsible for developing educational concepts and a unified education policy, and for creating laws, general binding regulations, and documents in education, such as curriculum documents. The ministry has a regional school office in each of the eight autonomous self-governing regions. According to the act, regional school offices provide professional counseling and supervision to the self-governing regions and municipalities. They also are responsible for special schools and facilities. For secondary schools, state administration has been transferred to the self-governing regions. For primary schools, preschools, and facilities outside of formal classes, administration has been transferred to municipalities.¹

Each primary and secondary school is managed by a principal who is responsible for implementing the curriculum, integrating professional and pedagogical standards into the teaching process, and supervising the teaching staff. The principal cooperates with a school board, comprised of teachers, parents, students, the municipality, and higher educational establishments that function as public control.

The majority of schools in Slovakia are state (public) schools, run and funded by the state. Nonpublic schools are private or church schools run by a person or legal entity. Private schools receive contributions from parents, as well as state subsidies.

Compulsory education in Slovakia is for a length of 10 years, from ages 6 to 16, and begins in primary school (*základná škola*). Students may complete their compulsory schooling when they finish the first year of secondary school. However, most students (83% of students in 2004) continue their studies and complete secondary school.²

The education system has four main levels: preschool, primary, secondary, and higher education.

Preschool education is noncompulsory and is designed for children ages 2 to 6. Preschools include kindergartens (*materská škola*) and special kindergartens (for children with special education needs). The goal of preschool education is to complement family education with activities that support the broader development of the child's personality, and prepare the child for attendance in compulsory school. Preschool education is organized according to the official document, *Program of Education and Training of Children in Kindergartens*, approved by the Ministry of Education. In the 2005–2006 school year, about 91 percent of children attended kindergarten prior to beginning compulsory schooling.³

Primary school (*základná škola*), beginning at age 6, consists of two stages: the first stage (grades 1 to 4) and the second stage (grades 5 to 9). The second stage of primary school is comparable to lower secondary education in other countries. Students entering primary school from socially disadvantaged backgrounds, who have not reached the maturity level necessary for schooling, may attend an extra year of school before starting first grade.

Secondary schools may be either grammar schools (*gymnázium*), secondary specialized schools (*stredná odborná škola*), or secondary vocational schools (*stredné odborné učilište*). Applicants must pass selective examinations for entrance into all types of secondary schools. Study at grammar schools is for either 4 years or 8 years. At 8-year grammar schools, grades 5–8 are recognized as 4 years of lower secondary education. Grammar schools offer academic courses in a variety of subjects and prepare students primarily for studies in higher education institutions. Students may choose some optional subjects according to the school program. Students graduate from grammar school by passing the school-leaving examination (*maturitná skúška*).

Presently, a new school law is under discussion to revise, for example, certain aspects of the current curriculum, such as its strictness. In the ongoing curriculum reform, there is a tendency to transform the curriculum into a two-level model consisting of the framework curriculum (national curriculum) and the school curriculum, with more competencies left for schools and teachers.⁴

Language and Population

Slovak is the official state language of the Slovak Republic, and most students receive education and training in the Slovak language. In certain regions, however, instruction also is carried out in the language of minority groups, primarily Hungarian, but also Ukrainian and German. In schools where a minority language is the language of instruction, Slovak is included among the other subjects taught.

Overarching Policies Related to Education and the Curriculum for Mathematics and Science Teaching at primary schools is based on study plans (*učebné plány*), syllabi (*učebné osnovy*), and content and achievement standards (*obsahový a výkonový štandard*), which are approved by the Ministry of Education. These curriculum documents determine the

number of lessons, the content specifications for all subjects at specific grades, and the level of achievement that students have to reach.

In the Slovak curriculum, there are several variants of study plans offering extended lessons in mathematics and science subjects, which allow schools to create differentiated classes. With respect to science, there are several variants of study plans for both the first stage of primary school and the second stage (lower secondary grades). Regarding mathematics, variants allowing for different numbers of mathematics lessons are offered only for the lower secondary grades. Schools have the autonomy to shape their own curriculum.⁵

The Mathematics Curriculum in Primary and Lower Secondary Grades

Summary of National Curriculum Guides for Mathematics Through Eighth Grade

Mathematics instruction in the Slovak Republic officially starts in the first grade of primary school. The curriculum is organized in a spiral form. In the primary grades (1–4), mathematics primarily focuses on arithmetic and algebra but also includes geometry. In the lower secondary grades, (5–9) mathematics consists of arithmetic, algebra, and geometry. Data displays also are integrated into some mathematics topics. Some mathematics topics also may be part of other subject areas, such as physics.

The goals formulated for the **primary level (grades 1–4)** are briefly described below.

- *First grade:* know numeration within 20 (e.g., writing and reading numbers, determining the number of objects, and comparing the numbers of objects); develop the use of pictures and a mixture of words and symbols to represent numerical activities and solve basic word problems involving comparing numbers; understand the meaning of plus and minus, memorize computation within 20, and solve basic word problems using plus and minus; and differentiate between geometrical objects (e.g., triangles and squares), draw lines, and model new shapes from geometric shapes according to a picture.
- *Second grade:* know numeration within 100; separate two-digit numbers into tens and units and combine two-digit numbers from tens and units; understand and use the commutative law for adding; know the basic mathematical terminology for adding and subtracting; memorize computation within 100; solve basic word problems related to adding and subtracting and solve complex tasks ($a + b + c$); multiply and divide within 20, understand the meaning of times and divide, and solve word problems using times and divide; understand dividing as splitting the whole into parts and the connection between the four operations; and draw a straight line and segment with a ruler, determine the point on and beside the segment, know the units of length (centimeter, meter), and determine the length of the segment (accuracy of measurement in centimeters).
- *Third grade:* memorize all basic connections for multiplying and dividing within 100, solve basic problems using multiplication and division, solve problems involving proportion and abstract, simple, and real-life situations; read and write three- and four-digit numbers within 10,000, determine the number of

persons and objects counting by 1,000, 100, 10, and 1, and separate or mark an object's category by 1,000, 100, 10, and 1; separate three- and four-digit numbers by thousands, hundreds, and units; multiply by 10, 100, and 1,000; compare three- and four-digit numbers; add and subtract simple problems mentally within 10,000; know and be able to use algorithms for writing, adding, and subtracting; check the results of computation, and solve word problems; draw and determine the length of the segment (accuracy of measurement in millimeters), and know the units of length (kilometer); and draw a circle given a point and distance with a compass, recognize the differences between rings and circles, draw triangles and quadrilaterals with a ruler, and know the facts about them.

- *Fourth grade:* multiply and divide mentally within 100 and above, divide within 100 with remainders, and multiply and divide simple problems mentally within 10,000; know and be able to use algorithms for writing and multiplying by one- and two-digit numbers and determine the results; solve word problems within 10,000 ($a + a: b$); and draw a perpendicular line to a segment, and compute the perimeter of a triangle and a quadrilateral.^{6,7}

The goals formulated for the lower **secondary level (grades 5–8)** are briefly described below.

- *Fifth grade:* divide natural numbers by arbitrary two-digit numbers with remainders and determine the result, understand place value by decimals, and use the four operations (mentally) with decimals; draw, measure, compare, and calculate angles; and understand the importance of measuring area in solving different word problems.
- *Sixth grade:* know the differences between natural and whole numbers and give examples of negative numbers from real life; order, compare, and compute whole numbers and decimals (also by number lines); understand the concept of fractions; compare, order, add, and subtract fractions; understand the importance of volume and the units of volume, and calculate volume and area; and recognize the relationship between three-dimensional shapes and their two-dimensional representation, construct triangles under different aspects, and compute the area and perimeter of triangles and quadrilaterals.
- *Seventh grade:* compute with fractions (four operations) and convert common fractions into decimals; order, compare, and compute rational numbers; understand the concept of mixed numbers and their use in computations, the meaning of variables, and the expression of proportions; recognize equality of two numbers or algebraic expressions; solve and determine the result of linear equations; convert percents to bar graphs or pie charts, and solve easy problems in the context of finance; know different kinds of prisms, compute the area and volume of prisms, describe congruent figures, and apply the theorem of congruent triangles; and construct median and centroid of triangles; construct figures with line symmetry, perform reflections and rotations of geometrical shapes.

- *Eighth grade*: write, read, and compute roots and squares; compute square and cube roots mentally, compute and simplify algebraic expressions, solve and determine results of linear equations and inequalities, draw equivalent representations of functions as ordered pairs, read from simple graphs, and understand the importance of some topics of combinatorics and probability; write the Pythagorean theorem, apply it to find the length of a side, and apply it in other situations; know the Thales' circle, and be able to apply it by solving geometric tasks.^{8,9}

The Science Curriculum in Primary and Lower Secondary Grades

Summary of National Curriculum Guides for Science Through Eighth Grade

Science instruction in the Slovak Republic officially starts in the first grade of primary school. The curriculum is organized in a spiral form. At the first stage, the subject, elementary teaching (*Prvouka*), integrates natural and social science (e.g., local history and geography), while science (*Prírodoveda*) is comprised of natural science topics (biology, earth science, and physics). All science subjects (natural history, physics, and chemistry) in the lower secondary grades are taught as independent subjects.

The goals formulated for the **primary level (grades 1–4)** are briefly described below.

- *First and second grade*: obtain knowledge of the real world, nature, and society; build skills through manipulation of living or nonliving things; build working skills by growing plants; form ways of maintaining good health and using good manners; traffic discipline; and learn to love the country and protect the environment.¹⁰
- *Third and fourth grade*: define and measure basic physical units (time, temperature, force, and mass), define chemical (flammability, color, hardness, etc.) and physical (solubility in water, etc.) properties of matter, describe changes in states of matter, describe the water cycle, and define the properties of air and identify their composition; differentiate between the properties of magnets and objects from other matters; describe the gravity of the Earth, the Earth's solar system, and the Earth's rotation on its axis; justify the importance of technology in everyday life; describe the properties of soil, rocks, white salt, and fossil fuels and their practical uses and protection; define and explain the common characteristics of living things and classification of living things, differentiate between living and nonliving things, between human produced nature and intact nature, define global problems, explain the importance of preservation of nature, and identify some reservations in Slovakia; identify and name some species of animals, plants, and mushrooms and describe the different environments in which the organisms live; identify and name major body structures (skeleton, muscles, and internal organs) and their functions in humans and animals, as well as the body structures of mushrooms and plants and their functions; describe the reproduction of plants and animals, the energy requirements of animals and plants, the importance of water and soil, the general steps in the life cycle in humans and other organisms, childcare for humans, and the most important differences between animals and humans; compare the appearance of animals

in different seasons, explain the importance of movement of animals and the importance of the dispersion of seeds by plants, and describe some features of animal behavior; define community; explain relationships in the community, the basic structure of a forest community, and the importance of animals, plants, and a forest community for humans, as well as its protection by humans; learn the development of the kinetic system and healthy living for humans, including the importance of sports and a balanced diet; and understand the harmful effects of smoking or other drugs on health.^{11,12}

The goals formulated for the **lower secondary level (grades 5–8)** are briefly described below. During grades 5–8, the topics in natural history (*Prírodopis*) are separated according to scientific discipline. In grade 5, the main area of emphasis is on botany; in grade 6, on zoology; in grade 7, on human anatomy; and in grade 8, on earth science. Environmental education is taught at the end of each grade. Observation and procedures are a part of the teaching units in each grade.

- *Fifth grade:* describe the basic classification of organisms, plant cells and the function of their compartments, and the major organs and organ system of plants and mushrooms; recognize the importance of plants in nature and the preservation of nature in Slovakia.
- *Sixth grade:* give examples of the relationships between plants and animals, describe the animal cell and understand its difference from the plant cell; describe major organ systems and their functions, reproduction, and interactions of animals within different environments; recognize the typical species of various environments and the basic classification of organisms, as well as the typical animal community in Slovakia; and identify major food relationships between animals and their importance for the balance in nature and preservation.
- *Seventh grade:* describe major organs and organ systems in humans and understand their functions; develop an appreciation of health and prevention; and understand the dependence of humans on nature, define some similarities and differences between humans and other living things, and recognize the evolution of humans.
- *Eighth grade:* realize the importance of nonliving nature for humans and the Earth in the solar system; describe the Earth's structure, differentiate between the components of the Earth's crust, describe major geological events and their impact on the environment, the Earth's history, and the major geological processes that formed the natural environment in Slovakia.^{13,14}

Instruction for Mathematics and Science in Primary and Lower Secondary Grades

Instructional Time

The number of lessons per week, which are each 45 minutes, depends on the variants of the study plan. The most basic study plan includes the following numbers of lessons.

- **Mathematics.** In grades 1, 8, and 9, there are four lessons per week (132 lessons per school year). In grades 2–7, there are five lessons per week (165 lessons per school year).
- **Science.** In grades 1–2, there are two lessons per week of elementary teaching and in grades 3–4, there are two lessons per week of science (66 lessons per school year). In grades 5–8, there are two lessons per week of natural history (66 lessons per school year) and one lesson per week in grade 9 (33 lessons per school year). In grades 6–8, there are two lessons per week in physics and one lesson per week in grade 9. In grade 8, there are two lessons per week of chemistry and three lessons per week in grade 9.¹⁵

Instructional Materials, Equipment, and Laboratories

Teachers are encouraged to use the recommended materials that are approved by the Ministry of Education. In respect to mathematics and science in the first stage of primary education, teachers may choose from special textbooks and worksheets. There are also additional teacher's books, which present instructional methods and types of lessons as well as suggested supplementary material. Approved textbooks are free and available for all students. Teachers also are encouraged to use various sources, such as film, video, TV, encyclopedias, models, or atlases. Science instruction in the primary grades also may include excursions and visits to museums. Additional materials used in the classroom are of the teacher's choosing and are dependent on the teaching method and available didactic resources (e.g., laboratories) in the school.

Grade at Which Specialist Teachers for Mathematics and Science Are Introduced

In the first stage, a single teacher usually teaches all or almost all subjects. Beginning in grade 5 (the second stage), all science topics are taught as independent subjects, and students are taught by several teachers who are specialists, generally in two subjects.

Use of Technology

In the past few years, extensive changes to the availability and use of technology have taken place in the schools. As part of the *Infovek* project, and through the support of sponsors, all schools were equipped with at least 5–10 computers and connected to the Internet by 2004. An important part of *Infovek* has been to train teachers in the basics of working with information communications technology and its practical application in the education process. The implementation process is in its initial stage and mostly depends on initiatives taken by individual schools and teachers.¹⁶

Teachers and Teacher Education

Education and Training for Fourth and Eighth Grade Mathematics and Science Teachers

In February 2002, a new Higher Education Act (No. 131/2002 of Law Code on Higher Education and on Change and Supplement to Some Acts) was adopted that implements all components of the Bologna Declaration in the Slovak higher education system. With respect to ongoing reform, higher education has three stages (bachelor's degree, master's

degree, and Doctor of Philosophy). The higher education institutions may admit students to accredited study programs only. The Ministry of Education, in cooperation with the higher education institutions, defined a list of fields of study for higher education and updated it at the beginning of 2003. This document is the basis for study programs in higher education. However, new study programs have been put into practice fully since the 2005–2006 school year.¹⁷

- **First stage (bachelor's degree).** This level is mainly viewed as preparation for the second stage of higher education. Over 3 years, students generally take courses with broader theoretical basics in the subjects necessary for the teaching profession (e.g., pedagogy, psychology, methodology, and biology), as well as in their areas of specialization. Graduates of the first stage also acquire qualifications, which allow them to fill some supportive pedagogical positions depending on their specialization.
- **Second stage (master's degree).** After another 2 years, students acquire their full teacher qualification. All the study programs at universities, which are preparing elementary teachers (teachers for the first stage of primary school) and secondary teachers (teachers for the second stage of primary school), include a prepracticum and a supervised practicum in the field, comprised of both observations and teaching. Teacher education for elementary teachers is organized within the autonomous field of preschool and elementary education, which integrates the traditional program for elementary teachers together with programs for preschool teachers. Teachers for the second stage of primary school and secondary school teachers typically choose to specialize in a combination of two subjects. Besides the faculties of education, students can also attend other faculties within a particular subject area. Teacher education and training is completed with the presentation of a thesis and passing the state examinations.
- **Third stage (Doctor of Philosophy).** Completion of higher education study at the second level is the basic condition for admission to a doctorate program. The standard length of study for the doctorate program is at least 3 years and at the most, 4 years.

Teacher Professional Development in Mathematics, Science, and Technology

Professional development opportunities are offered to educational staff for updating subject area knowledge and developing teaching methods and skills. A special act of the National Council regulates further education as a part of lifelong education. Teachers are expected to continue their education on an ongoing basis. Professional development is offered in the form of introducing new staff to practice, training in educational management, continuous education, specialized innovation study, specialized qualification study, and extended courses.

Several institutions provide further training for teachers, including higher education institutions, educational organizations of the Ministry of Education (e.g., the National

Institute for Education, the State Institute of Vocational Education, and pedagogical educational centers), and educational organizations of other ministries, which have established some schools or school facilities.

Examinations and Assessments

National or Regional Examinations

Presently, external evaluation takes place only at the national level. Since 2005, ninth grade students take an examination, Monitor 9, in the language of instruction and in mathematics. The results of this examination may be used by secondary schools as part of the formal admission process.

After completing secondary school, students take the school-leaving examination (*maturitná skúška*). Students have to pass the school-leaving examination in the Slovak language (or language of instruction), in a foreign language, and in two other subjects of the student's choosing. It consists of two parts, an external (written) test and an internal (both written and oral) test. The external examination is centrally prepared and administered on the same date throughout the country. Results of this examination are given to schools and may be used to determine eligibility and placement for postsecondary programs of study.

State control is exercised through the State School Inspection that conducts independent school inspections to monitor and evaluate achievement in education and training in schools. Such inspections involve collecting information on the management, organization, and quality of the educational process. The results are published in an annual report online. At present, the results collected through participation in the International Association for the Evaluation of Educational Achievement and Organisation for Economic Co-operation and Development surveys (TIMSS, PIRLS, and PISA) are used for evaluation as well.

Monitoring Individual Student Progress

Special general instructions for assessment and marking criteria are offered in the teachers' guide for all grades of primary school for both ongoing and final assessments. The level of acquired knowledge, skills, habits, and personal development is assessed through various procedures. Different principles are used based on the age group and subject being evaluated. Students are not given grades in the first grade but rather are provided with a verbal assessment (very good, good, or weak) based on their classroom performance in reading, writing, and mathematics.

Suggested Readings

- Ministry of Education of the Slovak Republic:
<http://www.minedu.sk>
- National Institute for Education: <http://www.statpedu.sk>
- National Report – Slovak Republic: http://www.bologna-bergen2005.no/Docs/Slovakia/SLOVAK_REPUBLIC.PDF
- State School Inspection: <http://www.ssiba.sk/>

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- 10 Ministry of Education of Slovak Republic. (1995). *Učebné osnovy prvouky pre 1. stupeň základnej školy* [Syllabi of elementary teaching for the 1st stage of primary school]. Bratislava: Author.
- 11 Ministry of Education of Slovak Republic. (1995). *Učebné osnovy prírodovedy pre 1. stupeň základnej školy* [Syllabi of science for the 1st stage of primary school]. Bratislava: Author.
- 12 Ministry of Education of Slovak Republic. (1998). *Obsahový a výkonový štandard z prírodovedy pre 1. stupeň základnej školy* [Content and achievement standards for science for the 1st stage of primary school]. Bratislava: Author.
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- 14 Ministry of Education of Slovak Republic. (2002). *Vzdelávací štandard s exemplifikačnými úlohami z Prírodopisu pre 2. stupeň základnej školy* [Educational standards with item example from natural history for the 2nd stage of primary school]. Bratislava: Author.
- 15 Ministry of Education of Slovak Republic. (2003). *Učebné plány pre 1. až 9. ročník základných škôl* [Study plans for the 1st to 9th stage of primary school]. Bratislava: Author.
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Slovenia

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Introduction

Overview of Education System

In the Republic of Slovenia, the constitution guarantees free education to all Slovenian nationals. Basic education is obligatory and funded from budgetary resources. The implementation of the education policy is the responsibility of the Ministry of Education and Sport. The ministry has the authority to decide on administrative matters related to education from preschool to secondary education and higher vocational education, including music, adult, and special needs education. Other higher tertiary education is the responsibility of the Ministry of Higher Education, Science, and Technology.

The Ministry of Education and Sport supervises the operation and management of public education institutions and other institutions in the field of education. The minister has the authority to issue delegated legislation that sets forth the requirements concerning human resources and facilities for the provision of education; specifies standards and criteria for the provision and funding of education; determines the enrollment procedures and the rights and duties of students, teachers, and other employees; defines the academic calendar; and specifies knowledge assessments.¹

The consultative bodies of the government, the Council of Experts for General Education, the Council for Technical and Vocational Education, and the Council for Higher Education, have been established to make professional decisions in their respective fields of competence, such as the adoption of national curriculum, syllabi, standards of knowledge, and examination syllabi, and the approval of textbooks. They also provide professional assistance in decision-making and preparation of legislation.

The compulsory elementary school curriculum was prepared and adopted by the National Curricular Council and the Council of Experts for General Education from 1998–2006.² The Elementary School Act specifies which school subjects are compulsory. Elementary schools have a statutory duty to offer a list of subjects from which students must choose two or three in the higher grades. By a statutory requirement, a certain number of social sciences, natural sciences, and a second foreign language must be offered.

National curricular documents consist of the syllabus for the 9-year elementary school and the national subject curriculum for compulsory and optional subjects. It also contains the definitions of cross-curricular content (e.g., how to use libraries and information technologies), extra-curricular activities, after-school classes and other forms of day care, out-of-school classes, and lists of approved textbooks and learning materials. The national subject curriculum guides includes general aims, objectives and core contents of the subject, didactic principles and recommendations, and knowledge standards.³

The Slovenian education system consists of preschool education; compulsory elementary education (grades 1 to 9); secondary education (grades 10 to 13), which is divided into vocational, technical, and general secondary education; and higher tertiary education.⁴

Preschool education is available for children between the ages of 1 and 6 and is not compulsory. Kindergartens provide day care and education with an emphasis on the individuality of each child.⁵ Day, half-day, and short programs are offered. The curriculum for kindergarten consists of six main content areas (movement, language, art, nature, society, and mathematics) and provides the framework for the selection of content and activities by teachers. Almost three quarters of all children are enrolled in kindergarten.⁶

Nine-year **elementary education** is divided into three, 3-year cycles. Elementary schools provide the compulsory curriculum, which consists of compulsory subjects, electives and activity days, and the extended curriculum (in which students are free to participate or not). It includes educational assistance for children with special needs, remedial and advanced classes for main school subjects, after-school care in grades 1 to 6, and after-school activities such as art, music, sports, and foreign languages.⁷ Schools are required to provide warm school meals. Children from socially and economically deprived families are entitled to school meals at a reduced price.

When selecting teaching methods, teachers can differentiate their work according to the ability of their students. The most common teaching method is internal differentiation, in which students of one or several classes can be divided into smaller study groups. In grades 7 to 9, the school may decide to group students into three ability levels for mathematics and foreign language education. The curriculum defines the standards of knowledge for each level, which students are required to achieve by the end of each grade or 3-year period.⁸

Secondary education includes 2- to 4-year vocational and technical secondary schools and 4-year general secondary schools, called *gymnasia*. *Gymnasia* offer general (the most advanced) or technically-oriented programs that lead to tertiary education. To enter university, students are required to pass an external national *matura* examination at the end of *gymnasia*. While following the same general mathematics course, in grade 13, students have to choose the basic or advanced level of the mathematics *matura* examination, which means less or more theoretical knowledge. Almost half of the student population is enrolled in general *gymnasia* programs, and about one third of them choose the advanced level of mathematics *matura*.⁹

Almost all elementary and secondary schools in Slovenia are public. There is one private elementary school, three private *gymnasias*, and some private vocational schools. All schools are free of charge, but parents pay for school accessories.¹⁰

Since 1999, Slovenia has been implementing a reform of the education system. The goals of the reform are a higher level of interconnectedness of disciplinary knowledge, an increased active role of students, internationally comparable standards and levels of knowledge, improvement in functional literacy, and an increase in the quality and longevity of acquired knowledge. The reform resulted in revised national curricular documents for all levels of pre-university education. Elementary school was changed from 8- to 9-year compulsory school. Children now enter grade 1 when they are 6 years old, a year earlier than before the reform.¹¹

One of the reasons for another reform of the curriculum was due to the poor results on TIMSS 2003. For mathematics, this means including arithmetic and algebra content in lower grades, intensification of mathematics in initial grades, and a reduced scope of the content in the final grades in order for students to consolidate their knowledge.

Language and Population

The official language is Slovenian, but there are Italian and Hungarian minorities. According to the 2002 census, there are 2,200 members of the Italian minority and 6,200 members of the Hungarian minority living in Slovenia. In the ethnically and linguistically mixed parts of Slovenia, the official languages also are Italian or Hungarian. In the northeastern part of Slovenia, Prekmurje, all schools are bilingual while in southwestern part of Slovenia, Slovenian Istra, schools offer Slovenian or Italian as the languages of instruction and examinations. Students in those schools have to learn Italian, Hungarian, or Slovenian as their second language, respectively.¹²

Emphasis on Mathematics and Science

Students are encouraged to individually do research work under the supervision of a mathematics or science teacher in order to compete at the national level as a young researcher.¹³ Students from all grades may participate in the national system of individual knowledge competition in each compulsory school subject. Competitions take place at the school, municipal, and national levels. High achievements at competitions are awarded with medals and are taken into account (together with final grades) for entrance into secondary schools that have limited enrollment.¹⁴

The Mathematics Curriculum in Primary and Lower Secondary Grades

Summary of National Curriculum Guides for Mathematics Through Eighth Grade

Mathematics is introduced gradually from grades 1 to 4. Children in grades up to grade 4 use only limited sets of natural numbers. The emphasis in the curriculum is on learning how to solve problems. Children are encouraged to explore by themselves and find their own ways to solve problems.¹⁵

Regarding the TIMSS framework,¹⁶ Slovene children up to grade 4 have not encountered decimal numbers and fractions. These are introduced in grades 6 and 7

and are immediately used for problem solving. According to the curriculum, children up to grade 8 are expected to do research and solve many mathematical problems such as equations and inequalities without the algebraic algorithm, and areas and perimeters of geometrical shapes without formulas. Only in grade 9 do they learn the formal way of solving problems and the related algorithms.¹⁷

In **grades 1 to 3**, the main subject areas are geometry and measuring (orientation in space, geometrical shapes, symmetry, use of tools, and measuring), arithmetic and algebra (natural numbers up to 1,000 plus 0, operations and their characteristics, operations with natural numbers up to 100 with renaming and up to 1,000 without renaming, and multiplication up to 10×10), logic (sets, categorizing by two attributes), and data presentations (histograms and tables).

In **grade 4**, in geometry and measurements, students learn to draw and recognize line segments, lines, and half-lines; draw rectangles, squares, disks, and circles with the help of templates; and perform operations with units of length, mass, and time. Arithmetic and algebra comprise adding and subtracting up to 10,000, multiplying and dividing by two-digit numbers, using appropriate operations for solving problems, solving expressions with brackets, and understanding the meaning of x in equations such as $a + x = b$, $x : a = c$. The rational numbers section includes learning how to divide the whole into equal parts and how to write down very simple fractions, such as one half, one third, and three fourths.

In **grade 5**, in geometry, students learn to design parallels and perpendiculars, draw shapes, calculate areas and perimeters of the square and rectangle, describe the cube and cuboid, and draw a net. In arithmetic and algebra, they learn to calculate up to 1,000,000; round numbers to tens, hundreds, and thousands; solve equations and problems upon consideration; solve numerical expressions; and calculate parts of a whole.

In **grade 6**, students first encounter decimal numbers and use them to perform comparisons and calculations, and they use fractions. In geometry, they learn to calculate volumes and areas of the cube and the cuboid. They encounter angles, calculating them and comparing their sizes. In algebra, they learn to solve equations and inequalities using tables and diagrams, as well as consideration.

In **grade 7**, the focus in arithmetic and algebra is on operations with fractions and percents. In geometry, it is on planning the design of a triangle and calculating its area and perimeter, and constructing shapes, angles, lines, and circles, as well as drawing reflections.

In **grade 8**, in geometry, students encounter the Pythagorean theorem and learn to use it in calculations of side lengths in triangles, trapeziums, rhombuses, circles, cubes, and cuboids. They calculate areas and perimeters of circles, lengths of arcs, and areas of sectors. In arithmetic and algebra, they learn about negative numbers, absolute values of numbers, how to continue sequences, and the use of exponentiation and roots. The notions of functions of variables represented by real numbers and of graphs of functions are introduced, with students learning to identify dependence between two quantities. They learn about direct and inverse proportionality, how to connect it to percents, and draw a graph. Equations are still only solved in an informal way.

The Science Curriculum in Primary and Lower Secondary Grades

Summary of National Curriculum Guides for Science Through Eighth Grade

The science curriculum stresses problem-related learning with special importance on experimenting. Students are supposed to do research by themselves and find their own solutions to problems.¹⁸

Up to grade 4, Slovene students will have been taught the majority of biological topics and topics related to earth science that were included in the TIMSS assessment. When it comes to physics, the discrepancy is somewhat larger. The distinction between heat and temperature is only introduced in grade 5 when students begin to develop abstract thinking.¹⁹ Compared to the TIMSS topics up to grade 8, students don't learn about solutions, acids, bases, movement, electricity, magnetism, and the biology of humans until grade 9. Earth science is mainly represented in physics. Geography predominantly focuses on the geography of countries of the world.

In **grades 1 to 3**, natural sciences are taught within the subject of environmental education,²⁰ which is designed to show the great complexity, diversity, and interpenetration of factors that are active in human's natural and social environments. Learning about the environment merges processes, procedures, and topics that are used by students to learn about the world they live in. The subject comprises natural and technical topics (chemistry, physics, biology, informatics, technical science, and technology), as well as social sciences (history, geography, communication science, sociology, economy, and political sciences). According to standards of knowledge, upon completing the third grade, students should have learned about themselves and the environment they live in; their own social past; their connection to nature; the importance of health; how to define the features of materials and bodies; and the physical principles of movement and forces, the Earth and the universe, space and time, weather, and sound.

In **grades 4 to 5**, natural sciences are taught within the subject of natural sciences and technology.²¹ Students learn to describe, explain, predict, and understand impacts on natural phenomena, as well as technical and technological procedures. The main topics of this subject in grade 4 are storage and transport, general human body operation, diversity in nature, and the movement of planet Earth (the creation of day, night, and shadows). The main topics in grade 5 are storage and transport; substances in nature; living creatures interacting with their environment and changing them; food chains and networks; the impact of the sun on weather; and data display.

In **grades 6 to 7**, the subject of natural science merges biology, chemistry, and physics.^{22,23} Lessons are formed as theoretical bases in combination with methods of direct observation, as well as laboratory, experimental, and field work. Obtaining information from various sources, students discover the core of the topics. They compare, accept, and consider critically the data and information, and they learn to analyze, connect, and generalize. According to the standards of knowledge, students having completed grade 7 should know about the interdependence of biotic and abiotic environments; properties of forests, water as a compound, and properties of aquatic ecosystems in specific living environments; properties of the sea, physical and chemical properties of

substances, and the differences between pure substances and mixtures; air properties and pollution; currents and energy; colors, the connection between light and the substance, and radiation, reflection, transmission, and absorption; the origin of light, refraction, and reflection, the speed of light, performance of mirrors and lenses, the occurrence of the image in the human eye, and the function of glasses; sound as waves, its origin, and terms related to it; and the occurrence of waves on the water's surface using rope and long spring.

In **grade 8**, natural sciences are taught as separate subjects: biology, chemistry and physics. Lessons in all subjects include observation and experiments, partly in school laboratories. The main topics of biology are biology as a science about life, the basics of ecology, diversity of life, and the systematics of evolution.²⁴ The main topics of chemistry are the structure of matter, chemical reactions, the atom and the periodic table, integration of particles, and the hydrocarbons family.²⁵ Apart from the main topics, teachers choose from the list of additional topics, which are optional. The standards of knowledge for individual topics that students should know are symbols of elements, compound formulas, notations of chemical changes, and reaction schemes for individual sets of topics. The main topics of physics are introduction to physics, forces, pressure, buoyancy, work, and energy.²⁶ Apart from the main topics, teachers choose from the list of additional optional topics. The standards of knowledge for individual topics that students should know are explanation of physical laws and phenomena by using appropriate quantities and formulas, use of physics measuring devices and the international measuring system, and reporting about measurements by using diagrams, graphs, and tables.

Instruction for Mathematics and Science in Primary and Lower Secondary Grades

Instructional Time

The school year is divided into two terms and comprises a maximum of 188 school days for students in grades 1 to 8 and a maximum of 183 school days for students in grade 9. Lessons are provided for up to 38 weeks per year, 5 days per week. The exact number of school days can decrease by a couple of days, depending on the distribution of national holidays.

In general, lessons are 45 minutes long. The maximum total number of hours of instruction per week includes 16.5 hours (22 lessons) for students in the first cycle, 19.5 hours (26 lessons) for students in the second cycle, and 22.5 hours (30 lessons) for students in the third cycle. Every school year the Minister of Education issues a school calendar, specifying the distribution of school days, school-free days, and school holidays. The syllabus specifies the exact number of yearly and weekly lessons for individual subjects, the number of discussion periods, and the minimum number of hours required for the implementation of the curriculum.²⁷

Teachers autonomously plan their teaching strategies, the organization of teaching activities as well as the teaching environment, and choose their own teaching and study materials and other teaching aids.

Each elementary school autonomously adopts its own annual work plan by taking into account the prescribed elements of the curriculum. The annual work plan specifies the distribution of teaching work and activities, the content and distribution of extra-curricular activities, as well as the scope and objectives of school's counseling service and library. The plan also defines involvement of the local community, parents in education, and activities important for a student's healthy life and development.²⁸

Instructional Materials, Equipment, and Laboratories

Many textbooks are available in Slovenia. To be authenticated for use in school, the books must follow the curriculum prescribed and not exceed its scope. They have to be authorized by the Council for General Education. Teachers autonomously decide which textbook they are going to use in each class from the list of authorized textbooks. Students are requested to buy their own school accessories (including calculators) and workbooks for solving additional problems. They can choose to buy their own textbooks or borrow them from school libraries for the whole school year.

The curriculum for mathematics and science prescribes materials to be used for teaching mathematics and science, such as manipulatives (counting material, cubes, geopanel, and geometrical shapes) that must be provided particularly to younger students, equipment for science experiments, and recommendations for computer use.

Schools have one or more laboratories or specially equipped classrooms for doing experiments for science subjects. The school is responsible for the distribution of material sources according to the needs of teachers, including buying laboratory equipment and materials for experiments.

Grade at Which Specialist Teachers for Mathematics and Science Are Introduced

In grades 1 to 3, all or most of the subjects are taught by general class teachers. Half of the lessons in the first grade of elementary school are assisted by a preschool teacher. During the second cycle (grades 4 to 6), specialist teachers become more and more involved in the teaching process. In the third cycle (grades 7 to 9), lessons are taught solely by specialist teachers. Therefore, students have specialist mathematics and science teachers beginning in grade 6. These teachers have university degrees in mathematics, biology, chemistry, physics, or the equivalent, if they are older.²⁹

Use of Technology

Students are allowed to use calculators for mathematics from grade 6 on and only in a limited scope.³⁰ Graphing calculators are not allowed for mathematics even in secondary schools. Students are expected, but not required, to use calculators for natural sciences starting in grade 5.

Computer rooms are available for student use at most schools and are equipped with many computers connected to the Internet. According to the mathematics curriculum, students should learn how to work on tables and data displays with computers. The curriculum for mathematics and science subjects also recommends some educational software for school use.³¹

Homework Policies

Schools have their own policies regarding giving, checking, and correcting homework. In most cases, homework is given at each lesson and is checked, not graded, during the next lesson.

Teachers and Teacher Education

Education and Training for Fourth and Eighth Grade Mathematics and Science Teachers

Teachers in public preschool institutions and schools must be properly qualified. The required qualifications are obtained through a combination of initial training, professional development, and practical training during the induction period. Teachers must complete their university degrees in education or a degree program in the appropriate subject area. If the teacher completes a university study program providing appropriate knowledge in the subject of teaching only (e.g., mathematics), the teacher must acquire pedagogical knowledge through a postgraduate, nondegree course leading to teaching qualification. Mathematics teachers must complete one of the following: (a) university study of education mathematics, (b) university study of education mathematics and education physics, technics, or computer science, or (c) university study of mathematics with additional pedagogical courses completed. Science teachers must complete one of the following: (a) university study of two education science subjects (physics, chemistry, or biology), (b) university study of one science subject and one subject from the field of science and technology (computer science, mathematics, or technics), or (c) university study of chemistry, physics, or biology with additional pedagogical courses completed.

To assure a smooth and gradual transition from study to work, newly graduated teachers are required to serve an induction period. Probationary teachers are employed for a limited period of time and have the same rights as other employees. They also are entitled to participate in additional education and training outside of their school or preschool institution. After completing the induction period or after a year of service in an educational establishment, aspiring teachers must pass a teaching certification examination. The examination is organized by the ministry and is free of charge for candidates. After passing the examination, teachers are awarded a teaching license and may be employed as tenured staff.³²

Teacher Professional Development in Mathematics, Science, and Technology

To ensure sufficient competency and professional development of teachers, they have the opportunity to participate in various forms of lifelong education, financed in full or in part by the ministry. With the school reform in professional development, teacher training became part of the teacher promotion system. The promotion system stimulates teachers and other educators to continually participate in professional development. Teachers can be promoted to three ranks: teacher-mentor, teacher-adviser, and teacher-counselor. To be promoted to a higher rank, teachers must submit proof of successful participation in a certain number of professional development courses, in addition to proof of professional accomplishments, such as participation in curriculum planning or international projects. Additionally, good student results help the teacher get promoted.

There are various forms of professional development provided: thematic conferences, licensing courses, and training courses offered by universities and other educational institutions. Schools are required to send every teacher to professional development for at least 5 days per year.³³

Examinations and Assessments

National or Regional Examinations

Students are required to take external national examinations at the end of grade 9 in their mother tongue, mathematics, and a third subject. The third subject is selected by the Minister of Education, in consultation with the Expert Council, from the range of compulsory subjects in the final grades of elementary school. The results are published in the students' elementary school certificates, but they must not be used as criteria for determining the students' overall success nor can they serve as criteria for admission to secondary schools.

National examinations are prepared by the National Committee in agreement with the Curriculum Committees for each individual subject. Examinations are organized by the National Examination Center. The National Education Institute of the Republic of Slovenia is responsible for analyzing and evaluating the results, proposing changes and amendments to the national subject curriculum, and planning further advisory and development activities in elementary schools. Topics and the content of the external examination are based on the objectives and goals of compulsory education and the standards of knowledge of individual subjects.³⁴

Monitoring Individual Student Progress

Teachers assess students' knowledge on a regular basis over the entire school year and provide students with information and oral feedback on their attainment of curricular standards. The knowledge acquired by students is assessed and evaluated through a system of tests.

Assessment and evaluation is carried out in accordance with the provisions of the Elementary School Act and the Regulations on Examination and Assessment of Knowledge and Advancement of Students in Nine-Year Elementary School, issued by the Minister of Education. Grades in the education process must not be used as a tool for disciplining or punishing students. Teachers are required to enable students to take an active part in the planning of assessments and evaluations and inform them on a regular basis about the criteria and methods for evaluation and assessment as well as students' grades.

The results of students in grades 1 to 3 are expressed in the form of descriptive grading, which includes the standards of knowledge the student has achieved. Second cycle students' results are evaluated by numerical grades and a verbal explanation of the grade. Students in the third cycle (grades 7–9) are given only numerical grades, which are used as admission criteria in secondary schools. Numerical grades are based on the

national 5-level grading scale as follows: 5 (excellent), 4 (above average), 3 (average), 2 (satisfactory), and 1 (fail).

Following the completion of each grade, elementary schools provide each student with a certificate containing his or her final grades in each subject. The overall success of each student is evaluated on the basis of these final grades in individual subjects, achievements at competitions and contests, learning effort, and participation in extra-curricular or other activities.³⁵

Grade Promotion and Retention Policies

Students in all cycles who receive positive (passing) grades for their overall success may advance to the next grade. Students in the first two cycles (grades 1 to 6) may proceed to the next grade even if they receive a negative (failing) final grade for their overall success. Students in the third cycle, who receive a failing grade in one or two subjects, may take a final make-up examination in the relevant subjects and may proceed to the following grade if they pass the examinations and successfully improve their failing grades prior to the beginning of the next school year. Students who receive negative (failing) grades in three or more subjects have to repeat the year. Students in grade 9 have several attempts to improve their final grades and can improve grades for a larger number of subjects. Decisions related to student progression are taken by the teacher assembly. The student and/or student's parents may appeal final grades.

Elementary schools have to offer additional remedial and advanced lessons (especially for mathematics) in grades 6 to 9. Students with learning disabilities may attend supplementary lessons. Gifted and talented students may progress faster and may complete the elementary school program in less than 9 years. Students who complete elementary school and receive a school-leaving certificate may continue their education at any general or vocational secondary school without any restrictions on the location of the secondary school.³⁶

Suggested Readings

Curricular documents and policies issued by Ministry of Education are published in Slovene and are available in the form of printed booklets or electronically. The following documents are available also in English:

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Sweden

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Introduction

Overview of Education System

A fundamental principle of the Swedish education system is that all children and young people shall have equal access to education, irrespective of gender, geographic residence, or financial circumstances.¹

The Swedish education system is highly decentralized. The allocation of responsibilities is based on the main principle that the parliament and government define national goals, while central authorities, municipalities, and principals and teachers ensure that educational activities are implemented in line with the legislative framework, and the national goals of education are achieved. State regulations for the education system are stipulated in the Education Act and passed by the parliament. The government sets the curricula and syllabi for compulsory school and is starting to make major changes to the Swedish education system, including changes to the syllabi and grading system.

The central authority responsible for the supervision of the school system is the Swedish National Agency for Education (*Skolverket*). Its foremost responsibilities include nationwide monitoring, national steering documents, national tests, evaluation, follow up, and supervision of all school activities. The task of the Educational Inspectorate is to determine whether and how well an activity is functioning in relation to the regulations stipulated in the Education Act, school ordinances, and national curriculum. This involves auditing and assessment at the municipal and individual school levels, with a focus on both the quality and legal aspects of the activities under inspection. The Swedish National Agency for School Improvement (*Myndigheten för Skolutveckling*) supports local development of work quality and the improvement of learning environments, stimulates the development of professional competence among educators, supports the broader use of information and communication technologies in education, and is responsible for the national program for school leadership education.

The administrative organization within a municipality, such as the allocation of responsibilities and financing, is not centrally regulated and varies among the

290 municipalities. On the basis of the Education Act, the curricula, and the syllabi, all municipalities are required to set general objectives for their schools in a school plan adopted by their municipal council. The school plan must clearly state the measures that the municipality intends to take in order to attain the national goals for education and should be regularly evaluated and updated. Each municipality is obliged to present an annual quality report.

Each school is required to establish a local work plan based on the national goals and the municipal school plan. The work plan should define issues that are not determined in the national steering documents, such as course content, organization, and teaching methods. This should be done by the head of each school in consultation with the teachers, other personnel, and representatives of students and parents.

In Sweden, there are only a few strictly private schools at the compulsory level, although there are a growing number of grant-aided independent schools (*fristående skolor*) at the compulsory and upper secondary level. Independent schools were first introduced in the 1990s. They are open to all and must be approved by the Swedish National Agency for Education. Independent schools receive municipal grants based on the number of students per academic year. Independent schools share the same national goals as the municipal schools. If an independent school does not comply with applicable regulations, the Swedish National Agency for Education may withdraw its approval.

The education system for children and youth consists of preprimary education, compulsory education, and upper secondary education.^{2,3,4}

Preprimary education and care are given at preschools (*förskola*), family day care centers (*familjedaghem*), and through open preschools (*öppen förskola*). The goal of these activities is to create favorable learning conditions and to stimulate a child's physical and mental development. In October 2006, 77 percent of all children, ages 1–3, and 97 percent of children, ages 4–5, participated in preschool activities. There also is a preschool class (*förskoleklass*) intended for 6 year olds with the goal of stimulating children's development and providing a sound base for education in compulsory school. In the current school year (2006–2007), 96 percent of all 6 year olds attended a preschool class. Preschool activities and preschool classes are regulated by the Education Act and through their curricula (*Lpfö98* and *Lp094*). Preschool activities are jointly financed by the municipal budget and parental fees. The preschool class is funded through the municipal budget.

Compulsory education in Sweden is carried out in a 9-year comprehensive school (*grundskola*) for children ages 7–16. If parents wish, children may start when they are 6. The compulsory school system comprises compulsory school (*grundskola*), Sami school (*sameskola*) for Sami-speaking children covering grades 1–6, schools for students with impaired hearing (*specialskola*), and schools for children with severe learning disabilities (*särskola*). Compulsory school is regulated by the Education Act and the curriculum (*Lp094*). All compulsory schooling is provided free of charge, and there are no entrance requirements. Compulsory education is funded through the municipal budget, which is financed by state grants and local tax revenues. Most students in compulsory education attend schools run by the municipalities, usually in their local area, but an increasing

number of students (8% in the school year 2006–2007) attend grant-aided independent schools. A Compulsory School Leaving Certificate qualifies students to apply for upper secondary school.

Upper secondary education (*gymnasieskola*) is open to students between the ages of 16 and 20. Almost all students leaving compulsory school (98% in 2006–2007) continue to upper secondary school. The upper secondary school is regulated by the Education Act and in the curriculum (*Lpf94*). Upper secondary education is divided into 17 national, 3-year programs. All of the programs offer a broad, general education and basic eligibility to continue studies at the postsecondary level. In addition to the national programs, there are a number of specially designed, individual study programs. Passing grades in Swedish or Swedish as a second language, English, and mathematics are required to be admitted to a national program. Students who do not have passing grades in these subjects are admitted to an individual program. Most students in upper secondary school attend schools run by the municipalities. However, 15 percent in the 2006–2007 academic year attended independent, upper secondary schools.

Language and Population

The national language and principal language of instruction is Swedish. Nearly 1 million of Sweden's total population (9 million) are immigrants or have at least one immigrant parent. There are five official minority languages in Sweden: Sami, Finnish, Meänkieli, Romani Chib, and Yiddish. Other languages of significance are Arabic, Persian, Spanish, and languages spoken in the former Yugoslavia. Since Sweden is a small country in terms of population and is heavily dependent on international trade, the use of English is widespread in business and in the academic world.

Second-language Instruction

Students with a native language other than Swedish may take Swedish as a second language. The goal is for students to acquire a functional mastery of the Swedish language that is comparable to students who have Swedish as their native language. Additionally, students with a native language other than Swedish have opportunities to further develop knowledge of their native language. Swedish as a second language has the important task of supporting students in their acquisition of knowledge in all subjects.

Emphasis on Mathematics and Science

Several, major national reports have been written and various measures have been taken in mathematics and science education as a consequence of national evaluations and earlier TIMSS and PISA studies. These include the Swedish Delegation on Mathematics and the NoT Science and Technology project.

The Swedish government⁵ has expressed concern in several areas associated with mathematics and natural sciences including the knowledge and interest of students, the competence of teachers, recruitment of teachers to higher education in science and engineering, and gender distribution in higher education. The Swedish government intends to make changes in teacher education and invest in the Teacher In-service Training

Initiative, managed by the Swedish National Agency for Education. The Swedish National Agency for School Improvement supports national resource centers in mathematics, science, and technology, and together with the National Center for Mathematics Education, is implementing an investment in municipal mathematics developers.

Overarching Policies Related to Education and the Curriculum for Mathematics and Science

The Swedish curriculum for compulsory education is valid nationwide. It is a rather brief and concentrated document (about 15 pages). The aim of the curriculum (*Lp094*) is to support the integration of activities to reach the goals of compulsory school.⁶ It stipulates the fundamental values and tasks for the school, as well as goals and guidelines with regard to norms and values, knowledge to be attained, the responsibility and influence of students, schools' responsibilities toward parents or guardians; cooperation between schools, leisure-time centers, and the surrounding world; assessment and grading; and the responsibilities of the school principal.

The only mention of mathematics in the national curriculum is that students should have a mastery of basic mathematical principles and be able to use these in everyday life. With regard to science, the curriculum states that a student should know and understand basic concepts and contexts within the natural sciences, as well as within technical, social, and humanistic areas of knowledge.

The various subject-specific syllabi are presented in a supplementary document.⁷ Like the national curriculum, the national syllabus is a rather brief and concentrated document that devotes about five pages to each subject. The syllabi contain sections describing the structure, aim, and nature of the subject and its role in education. The syllabus delineates two basic objectives: goals to aim for and goals to be attained. The goals to aim for indicate the orientation of the school's activities, while the goals to be attained state the minimum levels to be achieved by the students by the end of the fifth and ninth school years.

The Mathematics Curriculum in Primary and Lower Secondary Grades

Summary of National Curriculum Guides for Mathematics Through Eighth Grade

The general goal of mathematics in compulsory school is to provide students with the knowledge in mathematics needed to make well-founded decisions when making choices in everyday life. Knowledge in mathematics helps students interpret and use the increasing flow of information and follow and participate in decision-making processes in society. The subject should provide a sound basis for studying other subjects and for further education and lifelong learning.

The school, in its teaching of mathematics, should aim to ensure that students do the following.

- Develop an interest in mathematics, as well as confidence in their own thinking and their own ability to learn and use mathematics in different situations

- Appreciate the important role mathematics plays in different cultures and activities, and become familiar with historical contexts, where important concepts and methods in mathematics are developed and used
- Appreciate the value of and use mathematical forms of expression
- Develop their ability to understand, carry out and use logical reasoning, draw conclusions and generalize, as well as orally and in writing explain and provide the arguments for their thinking
- Develop their ability to formulate, represent, and solve problems with the help of mathematics, as well as interpret, compare, and evaluate solutions in relation to the original problem situation
- Develop their ability to use simple mathematical models, as well as critically examine the assumptions, limitations, and uses of these models
- Develop their ability to make use of pocket calculators and computers.

The aim should also be that students develop their numerical and spatial understanding, as well as their ability to understand and use the following.

- Basic numerical concepts and calculations with real numbers, approximate values, proportionality and percentages
- Different methods, measuring systems, and instruments to compare, estimate, and determine the size of important orders of magnitude
- Basic geometrical concepts, properties, relations, and propositions
- Basic statistical concepts and methods for collecting and processing data and for describing and comparing important properties of statistical information
- Basic algebraic concepts, expressions, formulas, equations, and inequalities
- Properties of different functions and their corresponding graphs
- The concept of probability in concrete random situations.

By the **end of the fifth year** in school, students should have acquired the basic knowledge in mathematics needed to be able to describe and manage situations, and solve concrete problems in their immediate environment. Within this framework, students should be able to do the following.

- Understand natural numbers and simple numbers in fractions and decimal form
- Understand and be able to use addition, subtraction, multiplication, and division, as well as be able to discover numerical patterns and determine unknown numbers in simple formulae
- Calculate natural numbers in their head and by using written calculation methods and pocket calculators
- Have a basic, spatial understanding and be able to recognize and describe some of the important properties of geometrical figures and shapes

- Compare, estimate, and measure length, area, volume, angles, quantities, and time, as well as be able to use drawings and maps
- Read and interpret data in tables and diagrams, as well as be able to make use of some elementary coordinates.

By the **end of the ninth year** in school, students should have acquired the knowledge in mathematics needed to be able to describe and manage situations, as well as solve problems that occur regularly in the home and society, which is needed as a foundation for further education. Within this framework, students should be able to do the following.

- Understand whole and rational numbers in fraction and decimal form
- Make estimates and calculations of natural numbers and numbers in decimal form, as well as percentages and proportions in their head and with the help of written calculation methods and technical aids
- Use methods, measuring systems, and instruments to compare, estimate, and determine length, area, volume, angles, quantities, points in time, and time differences
- Reproduce and describe important properties of some common geometrical objects, as well as interpret and use drawings and maps
- Interpret, compile, analyze, and evaluate data in tables and diagrams
- Use the concept of probability in simple random situations
- Interpret and use simple formulae, solve simple equations, as well as be able to interpret and use graphs for functions describing real relationships and events.

The Science Curriculum in Primary and Lower Secondary Grades

Summary of National Curriculum Guides for Science Through Eighth Grade

Parts of the common science syllabus are presented below. The subject-specific syllabi are more detailed. Earth science is taught within the science subjects of chemistry and physics, as well as within the social science subject of geography. The sciences (biology, chemistry, and physics) are taught either as an integrated subject or as three separate subjects. About 80 percent of the students receive grades in separate science subjects.

The common syllabus, written from a natural science perspective, together with the syllabi for the specific subjects, constitute a meaningful whole, with parts that support and complement each other. Together, the different parts form the national task for education in the sciences. Science studies are linked to knowledge in other school subjects.

The school in its teaching of science studies should aim to ensure that students should be taught the following.

- *Concerning nature and man:* believe in and develop their ability to see patterns and structures that make the world understandable, as well as strengthen this ability through oral, written, and investigatory activities.
- *Concerning scientific activity:* develop the insight that science is a specific human activity forming part of our cultural heritage; develop their ability to see how

man's culture influences and transforms nature; develop the ability to see inter-relationships between their observations and theoretical models; and develop their knowledge of how experiments are performed on the basis of theories, and how this leads to changes in theories.

- *Concerning use of knowledge:* develop their concern and responsibility when using nature; develop the ability to use scientific knowledge and experiences as a basis for examining their views; and develop a critical and constructive attitude to reasoning of their own and others, showing respect and sensitivity to the views of others.

By the **end of the fifth year** in school, students should be taught to do the following.

- *Concerning nature and man:* have knowledge within some scientific areas and familiarity with narratives about nature that are found in our own culture and that of others.
- *Concerning scientific activity:* carry out simple, systematic observations and experiments, as well as compare their predictions with actual results; be familiar with episodes in the history of science and have insight into different ways of explaining nature; and have insight into different ways of understanding nature through science, with its systematic observations, experiments, and theories, as well as through the approaches used in art, literature, myths, and sagas.
- *Concerning use of knowledge:* have knowledge of how man's curiosity about scientific phenomena has led to social progress; have knowledge of management of resources in daily life and about practical measures for conserving resources; and have insight into how arguments over daily environmental and health issues can be based on the use of personal experiences and scientific knowledge.

By the **end of the ninth year** in school, students should be taught to do the following.

- *Concerning nature and man:* have knowledge of the universe, Earth, life, and man's development; have insight into how matter and life are studied at different levels of an organization; and have knowledge of the cycles of nature and the flow of energy through different natural and technical systems on Earth.
- *Concerning scientific activity:* have knowledge of scientific ways of working, as well as be able to present their observations, conclusions, and knowledge in written and oral form; have an insight into the interaction between the development of concepts, models, and theories on the one hand, and experiences from investigations and experiments on the other; have insight into how knowledge of nature has developed and how this has both shaped and been shaped by man's perceptions of the world; and have insight into different ways of making nature understandable, through systematic observations, experiments, and theories, as well as by the approaches used in art, literature, myths, and sagas.
- *Concerning use of knowledge:* have insight into the difference between scientific statements and statements based on values; use their knowledge of nature, man, and his activities as arguments on issues concerning the environment, health, and interpersonal relations; provide examples of how the sciences can be used to create

not only better living conditions but also how science can be abused; and have insight into the consequences of different aesthetic views on environmental issues.

Instruction for Mathematics and Science in Primary and Lower Secondary Grades

Instructional Time

In line with the very decentralized education system, municipalities and schools are free to make their own decisions about the school year and teaching arrangements. Groups with students of the same age are most common. Flexible grouping also exists (e.g., groups that vary in different subjects and according to ability for short periods of time).

Children in need of special support have the right to receive an education in the regular school to the extent needed to be able to attain the goals of education. Most students with a need for special support are thus taught in regular classes. There also are a number of remedial classes for students with functional disabilities and for students with social and emotional problems.

The school year is divided into two terms and should comprise between 178 and 190 school days, respectively (Monday through Friday). The autumn term lasts from the end of August to the end of December. The spring term is from the beginning of January to the beginning of June. The exact dates vary from year-to-year and from one municipality to another.

Attendance is compulsory for a maximum of 8 hours per day (6 hours in the first 2 years of school). Usually, school days are shorter, especially for the younger children. The timetable, which forms part of the Education Act and has been adopted by parliament, guarantees each student a minimum of 6,665 hours of teaching in compulsory school. The timetable also gives the number of hours for each subject.⁸ The municipalities and the schools themselves decide on the distribution of teaching time across the 9 years of compulsory education, which includes 800 hours for biology, chemistry, physics, and technology; 900 hours for mathematics; 1,490 hours for Swedish; and 480 hours for English. Swedish, English, and mathematics occupy a prominent position in compulsory school education. Passing grades in these subjects are required to be admitted to a national program in upper secondary education.

Instructional Materials, Equipment, and Laboratories

Teaching methods and materials are not subject to central regulation. Teachers themselves choose teaching methods and topics to be covered in lessons (within the framework of the syllabus, the local school plan, and the school's work plan), as well as teaching materials such as books, audiovisual materials, and information and communication technologies. Teachers are limited only by financial restraints. The schools purchase the teaching materials from various publishers and distribute them to students free of charge.

Under the terms of the Education Act and the curriculum, students should be able to have an influence over the way teaching is organized and, as they become older and more mature, are given increasing responsibility for their own schoolwork.

Teachers and Teacher Education

Education and Training for Fourth and Eighth Grade Mathematics and Science Teachers

Public school teachers are municipal employees, while teachers in independent schools are employed by the schools. Recruitment of teachers and other personnel is carried out locally within each institution. Teachers without appropriate qualifications may be employed for a maximum of 12 months, if qualified staff are not available. This temporary contract may be renewed if qualified staff are still not available when the contract ends.

In October 2006, the proportion of female teachers in compulsory school (grades 1 to 9) was 74 percent. Throughout the 1990s, there was a shortage of trained teachers, and, in October 2006, 16 percent of the teaching force in compulsory school did not have formal qualifications to teach. In October 2006, the student-teacher ratio was about 12 students per teacher in compulsory school.⁹

Teacher training in Sweden has undergone a number of reforms. Between 1987 and 2001, there was no specialized training for the lowest grades. Instead, teachers were trained to teach grades 1 to 7, with an orientation in either mathematics and science or Swedish and social studies. However, teachers in both orientations received training in mathematics for the first three grades.

A second specialization was toward grades 4 to 9 (i.e., an overlap with grades 4 to 7), with three combinations of subjects: mathematics and science, Swedish and foreign languages, and social studies. In 2001, a new teacher-training program was launched that provided a high degree of individual choice with regard to the combination of subjects.

In 2005, specialization in teaching Swedish and mathematics for the lower grades became mandatory, which means that teachers of grades 1 through 7 are trained to teach mathematics in the first three grades. Consequently, teachers specializing in Swedish and social studies are generally not trained to teach mathematics and science in grades 4 to 7.

All teacher training is university based, which means that an upper secondary school certificate (9 years compulsory and 3 years upper secondary) is required for admission. Because of the general decentralization of the education system, universities have a high degree of freedom in arranging training in accordance with the framework set up by the government. A large part of training is arranged in mixed groups, where students choosing different subjects and age levels (6 to 18 years) study together, particularly in courses dealing with pedagogical matters and teaching practice. The number of years in teacher training ranges from 3.5 to 5 years for teachers at the compulsory level, with teachers of older students receiving longer training. Lower grade teachers have 3.5 years of training. All teacher training includes supervised teaching practice.

Teacher Professional Development in Mathematics, Science, and Technology

Those who employ teachers, municipalities, and independent schools are responsible for teacher professional development. The scope of this training is determined locally. Universities, other institutions, and freelance consultants offer courses, lectures, and study visits. A school or a school district also can arrange tailor-made trainings with universities. Teachers can apply for grants from the Swedish National Agency for School

Improvement or to various foundations to attend national or international conferences and meetings.

Examinations and Assessments

National or Regional Examinations

At the end of ninth grade, compulsory national tests are administered to assess students' achievement levels in three subjects: Swedish (including Swedish as a second language), English, and mathematics. The tests provide support for teachers in grading for the school-leaving certificate. Students are given national tests in the same subjects at the end of the fifth grade. Although these earlier tests are not compulsory, they are widely used as an indicator of progress. The national tests are designed by different universities in cooperation with the Swedish National Agency for Education.

Monitoring Individual Student Progress

Prior to the sixth grade, there are national diagnostic materials in Swedish and mathematics. For years 6 to 9 there are national diagnostic materials in Swedish (including Swedish as a second language), English, and mathematics. These voluntary materials can be administered when the teacher thinks it is suitable. The diagnostic materials are intended to highlight individual student's strengths and weaknesses in each subject. The diagnostic material for years 6 to 9 also is intended to provide an indication of students' chances of achieving the objectives for year 9 and to indicate how far students have progressed in relation to goals and objectives. Apart from test materials supplied by the Swedish National Agency for Education, several mathematics achievement tests, screening tests, and diagnostic materials are commercially available.

It is up to each local school to decide how to assess progress in different subjects. For mathematics, a number of schools use standardized screening tests to determine the general level of the school (usually in the middle grades, grades 4 or 5) or to identify students with difficulties in the lower grades. Teachers also are free to use other tests.

At least once a term, a student and his or her parent(s) receive progress reports and meet with teachers to have development dialogues, which mean discussing the student's progress and how learning can be stimulated and supported. The student is the focus of this meeting, but it also gives the adults involved with the child an opportunity to meet. Everyone taking part in the meeting should be familiar with the contents of the curriculum and syllabi, as well as the objectives and the working plan of the local school. These meetings are a substitute for annual progress reports or grading until grade 8, but they continue throughout compulsory school.

Since 2006, the teacher also is required to set up, in cooperation with the student and his or her parent(s), an individual development plan, which states what the student should strive to achieve. This plan is evaluated and revised at the meetings described above.

Grade Promotion and Retention Policies

Progression from year-to-year in compulsory school is automatic, and at no point do students have to pass examinations before they are promoted to the next level. Grades are awarded beginning in the eighth year of compulsory school.

Grades reflect student achievement relative to the national goals and grading criteria stated in the syllabus for the subject and are given on a three-grade scale: pass, pass with distinction, and pass with special distinction. A student who does not achieve the goals stated in the syllabus does not receive a grade in that subject but instead obtains a written assessment. The levels are related to the national criteria established by the Swedish National Agency for Education.

Suggested Readings

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Syrian Arab Republic

Suleiman Alkhatib, Deputy Minister

Dr. Omar Abouawn (NRC)

Ministry of Education

Introduction

Overview of Education System

The constitution of the Syrian Arab Republic emphasizes the right of each child to an education, which is free and compulsory from grades 1–9. The principles of the democratization of education and equal opportunity are available to all citizens without exception according to their will, abilities, and desires.¹ The 1981 Compulsory Education Law No. 35 applies to all Syrian children and to those with the same rights (Palestinians living in Syria) who are at the compulsory school age.²

Education in the Syrian Arab Republic is centralized, and the Ministry of Education is responsible for supervising and controlling the curriculum and the goals of teaching, including the interaction and the integration of the active teaching elements (teacher, student, and books).³ The ministry also is responsible for newly written course books that make available teaching methods.⁴ The curriculum emphasizes the participation of student's families.

Before 2002, education was compulsory from grades 1 to 6, but, the Basic Education Law No. 32 combined elementary and primary education into one basic education stage and made it compulsory from grades 1 to 9. This stage ends in a government examination, after which students who pass this test are granted a certificate of basic education. The bylaws of basic education also include methods of enforcement of basic education, as well as the distinguishing features of this phase. At the same time, the bylaws also include the terms of reference for basic education and for overcoming any obstacles that may hinder the good enforcement of the law.

While the kindergarten phase for children ages 3 to 5 is not compulsory, the Ministry of Education is building new kindergartens and also promotes kindergartens built by the private sector. The education bylaws of basic education were amended in 2004 on the basis of field comments that were received and divided basic education into the following two cycles.

- **First cycle.** From grade 1 to grade 4, those who teach in this cycle are tutors; assistant teachers for sports, art, music education, and English; and other teachers who are university graduates, in case of need, for this cycle.
- **Second cycle.** From grade 5 to grade 9, those who teach in this cycle are specialized teachers, assistant teachers, and basic education tutors (who have a Bachelor of Arts degree).

The Ministry of Education is responsible for providing educational services to its 14 directorates in the governorates. Each education directorate is responsible for the schools in their governorate.

According to the 2007 census, 98 percent of schools in Syria are public, 1.8 percent are private, and 0.2 percent are United Nations Relief and Works Agency schools for children who are refugees.

Language and Population

According to the latest census in 2007, the population in Syria was 19.172 million, including 9.798 million males and 9.374 million females. In 2005, 18.7 percent of the population did not read or write. According to the constitution, Arabic is the official language in the Syrian Arab Republic, with education being provided mainly in Arabic. English is taught from grade 1 in the basic learning stage as the primary second language, and French is taught in grades 7–12.

Overarching Policies Related to Education and the Curriculum for Mathematics and Science

The process of revising the mathematics curriculum in the pre-university stage is an ongoing process, and it is based on fieldwork by teachers and educational supervisors who contact specialists on curriculum in foreign countries. The fundamental change in the mathematics curriculum began in grade 1 in 1997 and was extended to grade 12 in 2006.

The government of the Syrian Arab Republic, represented by the Ministry of Education, has been developing the mathematics curriculum. In 2005, mathematics and pedagogical experts from schools and universities in Syria established the international criteria for mathematics.

Developing the science curriculum in the basic and presecondary stage has been the goal and an ongoing process for the Ministry of Education in the Syrian Arab Republic. In the late 1980s, the ministry began to write and compile schoolbooks. However, the effort lacked a clear vision. Since 1994, the initiative became a priority and the science curriculum was developed and piloted, and then evaluated in the 2003–2004 school year. The new curriculum concentrated on developing scientific thinking skills and was considered effective. Still, the most important development was the ministry's efforts in 2005 to adopt quality standards for the education curriculum. The ministry has set criteria for all schoolbooks so that they comply with international standards.

The ministry has emphasized learning and teaching quality in the presecondary stage, so that students will have learning skills that are equal to those of other students

in developing countries. Quality learning involves defining target goals that are parallel to the international view about what students should know and be able to do in all learning stages.

The Mathematics Curriculum in Primary and Lower Secondary Grades

Summary of National Curriculum Guides for Mathematics Through Eighth Grade

The **first stage (grades 1 to 4)** in the basic learning mathematics curriculum aims to teach students the following skills and knowledge.

- Numbers, including interpreting the meaning of fractions in different contexts, involving measurements and quotients
- The relationship between numbers, including number fractions, comparison of numbers, the spatial value of counting, and number forms (but not ordinal counting)
- Numeric thinking and evaluation
- Arithmetic processes, including the meaning of the process (when to add and when to subtract) and the relationship between arithmetic problems (multiplication and addition, multiplication and division, and addition and subtraction)
- Measurement procedures and systems
- Diagrams and pictograms to classify, categorize, and organize data and realize the concept of dimensions
- Types of numbers (ordinal, cardinal, and fraction) and how to use them in arithmetic problems.

By the end of the **second stage (grades 5–9)** of basic education, students are required to recognize the following.

- The concept of the group and the relation between the figure and the group and how to employ this concept in classifying the group of real numbers
- The relationship between the number groups and the characteristics of each group
- Order and equality
- Algebraic symbols and how to use them to form and solve mathematical problems
- Properties and characteristics of two- and three-dimensional geometric shapes and how to think about and discuss geometric shapes
- The location of positions and how to describe parallel relations using coordinates
- Data and probabilities, including collecting data and organizing and presenting it in a suitable way and presenting conclusions and expectations based on the data, as well as understanding basic principles in probability and their applications
- Problem solving, including building good mathematical knowledge through problem solving
- Mathematical concepts to solve everyday problems and think mathematically
- Mathematical language to express daily life matters and find solutions.

Additionally, by the end of **eighth grade**, students are expected to be able to do the following.

- Understand the concept of proportional numbers
- Perform operations in the proportional numbers group
- Use equations to solve everyday life problems
- Use diagrams and data tables
- Apply facts related to everyday life
- Use different methods to solve everyday life problems
- Acquire accuracy in performance and expression
- Employ arithmetic operations and present them in diagrams
- Master mathematical skills to succeed in the workplace.

The Science Curriculum in Primary and Lower Secondary Grades

Summary of National Curriculum Guides for Science Through Eighth Grade

These criteria describe the amount of learning, skills, and basic principles that should be taught and learned at school through grade 8. These criteria can be found in the goals, content, methodologies, evaluation, and the educational environment. The ministry is interested in students' learning the following.

- Scientific facts and principles and basic scientific concepts (scientific knowledge)
- Basic scientific processes (skills)
- Understanding the real world.

Scientific knowledge or the concepts, facts, and principles of basic science are presented in biology, geology, physics, and chemistry. It is expected that students understand the relationship between these areas of science, look at science with a comprehensive vision, and conceptualize different phenomena. The basic scientific concepts in the science areas include the following.

- *Biology and geology*: species of animals from the local environment; the differences and similarities between animals and plants and between vertebrates and invertebrates; and land and the environment, including an understanding of environmental balance, fossils, the age of the Earth, and geological durations.
- *Physics and chemistry*: electromagnetic, light, and chemical reactions.

Basic scientific processes or skills refer to the actions implemented by the student in order to learn, including observation, measurement, and deduction and classification, investigation, the reaching of conclusions, reasoning, forecasting, diagram interpretation, and experimentation. These skills enable the learner to observe, think, meditate, experiment, investigate, and discover instead of receiving information and memorizing it.

Understanding the real world can be achieved by developing an appreciation for the greatness of nature and its ethical treatment, an understanding of relationships between

people, and the rules of preserving health. In this framework, the concepts of science are distributed as follows.

- *The first stage, grades 1 to 4:* know the parts of the body; recognize plants and their shapes; describe animal habitats and human body changes and development; recognize the sources of sounds and the association between sounds and the sense of hearing; be interested in the cleanliness of the body, home, class, and school; explain the role of the tree in protecting the environment; appreciate the importance of water and air for humans, animals, and plants; understand the relation between force and action; and understand the existence of organisms and inanimate objects in outer space.
- *The second stage, grades 5 to 9:* classify organisms into kingdoms, understand how they grow, and the role of cell assimilation, breeding and its mechanisms, as well as the principles of heredity; understand renewable resources and limited resources; learn about the importance of rocks in nature, in addition to the structure of the ecological system and the biosphere and the changes that occurred throughout the history of the Earth; learn the structure of the atom; know the role of carbon in organisms; use logarithms to determine the relation between motion and force in nature; and understand the effects of electric current.

From grades 1 to 6, one book is used to teach general science (biology, physics, and chemistry), and the subject is taught by one tutor. In grades 7 to 9, biology is in one book while physics and chemistry are in a separate book, and specialized teachers teach the subjects.

Instruction for Mathematics and Science in Primary and Lower Secondary Grades

Instructional Time

The Ministry of Education sets the teaching plan for each subject. For example, science and health education are allotted three periods a week from grades 1 to 7 in basic education and four teaching periods a week from grades 8 to 9. There are four teaching periods of mathematics a week from grades 1 to 8 in basic education, while five periods a week are allotted to the subject in the ninth grade.

Instructional Materials, Equipment, and Laboratories

In the Syrian Arab Republic, teaching methods include all equipment, tools, and the different techniques used by the teacher to investigate and convey educational knowledge to students inside or outside of the classroom in order to develop teaching processes and fulfill the goals of teaching.

Through the Ministry of Education, the directorate responsible for educational techniques studies and designs teaching methods and techniques and produces them to comply with the education curriculum. The directorate in charge of teaching methods holds training courses for teachers, tutors, supervisors, technicians, laboratory workers, and librarians in the following areas.

- Using teaching methods
- Producing teaching methods for science and mathematics out of simple and available materials in the local environment
- Using advanced laboratory equipment, keeping it running, and maintaining it.

The educational television channel was founded in 2006 and is supervised by a directorate. This channel helps eliminate illiteracy and spread educational awareness among different sectors of society by enriching the knowledge of teachers, learners, and masters, and developing their skills and experiences in informatics (new uses of technology). The Ministry of Education produces educational lessons on television, in coordination with the Directorate of Curriculum and Supervision and the Directorate of Informatics, in compliance with the new curriculum.

Grade at Which Specialist Teachers for Mathematics and Science Are Introduced

Those who teach in the second cycle, from grade 5 to grade 9, are specialized teachers.

Use of Technology

The world is witnessing a knowledge revolution accompanied by the development of informatics used in all fields of life. Therefore, in Syria, there was a need to coordinate plans for developing the curriculum and the national plan for informatics. This resulted in a concentration on the use of informatics, and adopting new, modern pedagogical methods in education.

The Ministry of Education, through the Directorate of Informatics, is working on implementing training courses in this area for workers at the central administration, and the workers at the subdirectorate, in accordance with the training plan for reinforcing students learning experiences. It also is working on linking secondary schools (both branches) with the ministry's network and linking all schools with email service and the Internet.

Teachers and Teacher Education

Education and Training for Fourth and Eighth Grade Mathematics and Science Teachers

In order to be qualified as a teacher, the teacher training program includes three main modules.

- *Module one:* scientific academic preparation within their field of scientific specialization.
- *Module two:* professional preparation, including educational and psychological studies that enable the teacher to organize strands and teach learning experiences and facilitate the process of teaching and learning science.
- *Module three:* general education preparation, aimed at providing the teacher with a general education.

In order to work as a teacher of mathematics and science in the education system, a title from a teacher training college or a certificate verifying that someone is a teacher or

has a university degree in mathematics and science is required, in addition to a diploma in pedagogy.

Candidates for public school positions are chosen through a merit-based competition and the candidate's graduation marks. The competition includes testing and a personal interview.

Teacher Professional Development in Mathematics, Science, and Technology

New teachers must attend professional development courses during the year and summer vacations. There are continuous courses, and they include scientific topics, in addition to effective methodologies in science and mathematics.

The Ministry of Education also has created a committee of head teachers and supervisors. They are offered training on methodology and structural evaluation and diagnosis in order to provide specialization in these fields and to upgrade their performance. The specialized supervisors also provide the teachers with training in their governorates on modern, active methodologies and on the recent scientific discoveries in mathematics and science.

The ministry is developing a professional development program for teachers in accordance with the recent forms of electronic teaching and remote teaching. The program is associated with training used for similar programs that were successful in other countries.

The ministry has a project that promotes and prepares teachers to teach the new curriculum and integrate technology into education through the system of open learning in the Ministry of Higher Education. In the 2004–2005 school year, it prepared 7,809 teachers; in 2005–2006, 8,079 teachers; and in 2006–2007, 8,500 teachers. It also prepared 1,695 teachers in training who needed diplomas in pedagogy via web learning in association with the Syrian Virtual University.

Examinations and Assessments

National or Regional Examinations

Assessment is an organized, oriented, and planned process that includes detecting the strengths and weaknesses of students. The process of assessment is comprehensive and includes three educational goals—cognitive, intuitive, and professional.

The school year is divided into two terms. The Ministry of Education distributes the subject of the curriculum along these terms and determines the beginning and the end of each term. During each term, there are oral tests, training and assignments, and monthly tests (written, oral, or practical, according to the nature of the subject and the standard of the class). For grades 1 to 4, the student passes into a higher class if he or she gets the required marks and fails if he or she is weak in one of the following subjects.

- Reading, composition, poetry, and memorization
- Writing, dictation, calligraphy, and grammar practice
- Mathematics (arithmetic and geometry)

For grades 7 to 8, the following tests and examinations take place during each of the terms.

- **Oral and practical tests and written assignments.** The average mark on oral and practical tests and written assignments constitutes the student's class credit in each term. This mark is distributed as follows: 25 percent from oral tests, 25 percent from homework assignments and related activities, and 50 percent from written tests, except for the English language, which has special instructions.
- **End of term examination.** The examination lasts 6 days and the timing is determined by ministerial instructions.

A student's final mark for the school year in each subject is calculated by adding the student's class mark to the term examination mark and taking the average. The average of these marks at the end of the two terms is the final mark.

The student succeeds and is promoted to the next grade when he or she fulfills the following conditions.

- The collective final marks for all subjects must be at least 50 percent of the total mark
- A final mark in each subject must not be less than 40 percent
- A final mark in Arabic language must not be less than 50 percent.

For the ninth grade, at the end of the school year, the students take a general and unified test for the basic learning certificate. It is a comprehensive state examination at the country level. For 10th grade, the required mark to succeed is higher and determined by the ministry. At the end of the 12th grade, students take a general state examination at the country level for entering the university. Entering the university requires certain marks decided by the university. Therefore, the mark that the student gets in the state examination is important and determines whether the student can go on to the university.

Grade Promotion and Retention Policies

Promotion in basic education is not automatic. The student is introduced to tests at school, as mentioned above, in order to proceed to the next grade.

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Thailand

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Introduction

Overview of Education System

The Thai National Constitution affirms that every citizen has the right to obtain equal access to quality education. A free, 12-year basic education is provided by the state nationwide. Until 1999, Thai education was highly centralized by the state, under the administration of the Ministry of Education. The 1999 Education Act introduced changes into the Thai education system, and the education provision authority was decentralized and is now responsible for the state, local administration organizations, and private sector. All types and levels of education can be provided by state educational institutions, as well as learning centers that are organized by individuals, families, communities, religious institutions, and local administration organizations. The following is a description of the three structures of the Thai educational administration and management.

- **The state.** The Ministry of Education, through its central agencies, is responsible for making decisions regarding national education policies, educational planning, and educational standards.
- **Local administration organizations.** Local organizations, such as provincial administration organizations or municipalities, are authorized to provide educational services at all levels commensurate with their readiness, suitability, and local needs. Educational budgeting and allocation are provided by local administration organizations themselves. The state, through the Ministry of Education, prescribes criteria and procedures for assessing the local administration organization's readiness to provide educational services and assists in enhancing their capacity to follow the national education policies and required standards.
- **Private sector.** The private sector can participate in providing all types of education at all levels. The Ministry of Education oversees and assists in enhancing their capacity to follow national policies and required standards. Subsidies, tax rebates, and exemptions for educational expenditures are provided to support the private sector on their education provision.

In conformity with the national education reform policy, 178 educational service areas in 76 provinces were set up to assist communities in participating in the educational provision. Each educational service area has an Area Committee for Education, responsible for approximately 200 educational institutions with student populations of 300,000 to 500,000. Each school is responsible for its own administration and management relating to academic matters, budgets, personnel, and general affairs. Oversight is through a 7- to 15-member board consisting of representatives of parents, teachers, community groups, local administration organizations, alumni, and academics.

Education in Thailand is provided in three forms: formal education, nonformal education, and informal education. **Formal education** comprises basic education and higher education. Basic education consists of 6 years of primary education and 6 years of secondary education, as shown in Exhibit 1. A 9-year compulsory education requires that students enroll in basic education from age 7 until the age of 16, with the exception of those who have already completed grade 9. Preprimary education is provided, but is noncompulsory, with the purpose of preparing children in their physical, emotional, social, and intellectual development prior to entering basic education. Higher education refers to education after basic education at the diploma, associate, and degree levels.

Exhibit 1 Preprimary Education and Basic Education

Education Level		Number of Years of Education	Student's Age (Years)
Preschool Education	Preprimary education	3	3–5
Basic Education	Primary education	6	6–11
	Secondary education	6	12–17
Higher Education	Lower than bachelor's degree and bachelor's degree	2–6	18–21
	Graduate school	2+	–

Nonformal education primarily targets the school-age population who have missed out on formal schooling and the population above school age. This includes prison inmates, the labor force, the disabled, conscripts, and Thai people in foreign countries.

Informal education refers to education that is learned according to one's interests, potential, readiness, and opportunities available from individuals, society, the environment, media, or other sources of knowledge. The state, through the Ministry of Education and other ministries, is involved in providing lifelong learning through information dissemination, educational activities, and academic and professional programs.

The government provides financial supports, including the governmental budget and or subsidies for preprimary education through higher education in both public and private institutions and nonformal education, as well as subsidies for educational expenditures of the Bangkok Metropolitan Administration and local administration organizations. In 2005 and 2006, the government's budget for education expenditure was 3.7 percent of the national gross domestic product.¹

At present, the challenge for Thai education is the shortage of teachers. According to the study conducted by Ketesingh,² in the 2006 fiscal year, 19,107 schools under the Office of Basic Education Commission or 59.9 percent of the total schools had a shortage of teachers. Based on the study conducted by Siribunpitak,³ among the 56,000 mathematics and science teachers nationwide, only 33,800 teach in subject areas relevant to their training backgrounds.

To solve this problem, the Ministry of Education provided teacher training in subject content and pedagogy methods for teachers who do not have relevant training backgrounds. The Institute for the Promotion of Teaching Science and Technology is responsible for the teacher training. The training strategies focused on providing training for core representations of mathematics and science teachers so that they can transfer what they learned from the training to their colleagues. More than 90 percent of mathematics and science teachers throughout the country participated in the institute's training programs.

Increasing the number of new teachers in the system is another strategy to solve the teacher shortage. In order to make this possible, a number of teacher training projects have been introduced, such as a project that promotes gifted teachers in mathematics and science; the Science, Mathematics, and Technology Excellence Development Project; the Teacher Professional Development Project; and the Project on Urgent Development for Bachelor Graduates in Mathematics.

Language and Population

A large majority of the more than 62 million citizens of Thailand are ethnic Thai. Less than 10 percent are ethnic minorities. Thai is the only official language in Thailand.

Second-language Instruction

Instruction in all schools is offered primarily in Thai. However, in some international schools and ethnic minority group schools, the language of instruction can be in both Thai and foreign languages (such as English and Chinese).

Overarching Policies Related to Education and the Curriculum for Mathematics and Science

The goals of mathematics and science education in Thailand are to prepare citizens to improve their quality of life, give students the basic tools for lifelong learning, and enhance happy coexistence in the global community.

Before 1972, the Thai curriculum in mathematics and science was developed and implemented nationwide by the Ministry of Education. Then, in 1972, The Institute for the Promotion of Teaching Science and Technology was established as an independent organization with its main duty being to assist and promote science and technology teaching throughout the nation. The institute conducted research on how to improve the quality of mathematics and science teaching methods and evaluate students' learning outcomes, as well as revise the curriculum for mathematics and science, mostly for basic education. The institute was assigned by the Ministry of Education the task of revising the 2001 curriculum in mathematics and science, which consists of core requirements and

learning standards as prescribed by the Basic Education Commission. The curriculum's specific content is directly related to local needs and contexts and developed by the educational institution.

One of the institute's major missions is to develop and nurture talents among teachers and students in mathematics, science, and technology. It promotes talents through various programs including the National Science and Mathematics Olympiads and the International Science and Mathematics Olympiads, which emphasize an academic atmosphere that attracts students' interests in science and technology, promotes science and mathematics teaching, and provides opportunities for young talents to develop their intellectual capacity in science and technology to their full potential. The third program that nurtures talent in science and technology is the Development and Promotion of Science and Technology Excellence Project. The Science, Mathematics, and Technology Excellence Development Project seeks out and promotes young talent in science and technology, as well as attracts young peoples' interests in learning science and technology. Finally, the Teacher Professional Development Project awards scholarships up to the doctoral level to science and mathematics bachelor's degree holders. Since 2005, this project has produced 580 science and technology teachers annually.

Based on the 2001 Educational Reform Act, Thai mathematics and science texts are not mandated to be developed by any specific organization. However, mathematics and science texts developed by either the government or private organizations are subject to approval by the Bureau of Academic and Educational Standards. The Institute for the Promotion of Teaching Science and Technology, a governmental agency, developed the curriculum for both mathematics and science, as well as texts for basic education that have been in use since 2003.

The Mathematics Curriculum in Primary and Lower Secondary Grades

Summary of National Curriculum Guides for Mathematics Through Eighth Grade

The mathematics curriculum⁴ sets standards and the core curriculum in the following six subject content areas: numbers and operations, measurement, geometry, algebra, data analysis and probability, and mathematical skills and processes. Educational standards for mathematics learning in each content area are as follows.

- **Numbers and operations.** Students are expected to understand various ways numbers are presented and used in the real world, understand the effects of operations on numbers and the relationships among those operations, use estimation in computing and solving problems, understand number systems, and use properties of those number systems.
- **Measurement.** Students are expected to be able to understand measurement concepts, measure and estimate quantities, and solve measurement problems.
- **Geometry.** Students are expected to be able to describe and analyze two- and three-dimensional geometric figures and use visualization, spatial reasoning, and geometric models in solving problems.

- **Algebra.** Students are expected to be able to describe and analyze a variety of patterns, relations, and functions, and use expressions, equations, inequalities, graphs, or other mathematical models to represent situations and interpret and apply them to solve problems.
- **Data analysis and probability.** Students are expected to be able to understand and use statistical methods and probabilities to make reasonable predictions and use statistical and probability knowledge to make decisions and solve problems.
- **Mathematical skills and processes.** Students are expected to be able to solve problems, use reasoning, use mathematics in communication and representation, connect mathematical knowledge within and outside the mathematics context, and think creatively.

According to the mathematics core curriculum, subject areas progress from simple to more complex in ascending grade levels. Instruction and assessment are expected to build a foundation for students so that continuity and connectivity in mathematics are maintained from grade 1 to grade 12.

The Science Curriculum in Primary and Lower Secondary Grades

Summary of National Curriculum Guides for Science Through Eighth Grade

Based on the science curriculum,⁵ educational standards were set for learning science at the basic level and they provide the core curriculum for basic education in science. The core curriculum emphasizes developing students' ability to do the following.

- Understand the principles and theories for basic science
- Understand the scope, limitations, and nature of science
- Develop thinking skills, imagination, ability to solve problems, communication skills, and the ability to make decisions
- Utilize knowledge and understanding of science and technology for the benefit of society and social life
- Bestow the scientific mind, moral, and ethical sense of responsibility, and proper values.

Subject areas in the science core curriculum consist of eight principal strands: living things and living process, life and the environment, matters and properties, force and motion, energy, transformation processes on Earth, astronomy and space, and the nature of science and technology.

According to the science core curriculum, subject areas progress from simple to more complex contents in ascending grade levels. Instruction and assessment are expected to build the foundation for students so that continuity and connectivity in science are maintained from grade 1 to grade 12.

Instruction for Mathematics and Science in Primary and Lower Secondary Grades

Instructional Time

Mathematics and science are introduced in the first primary grade. According to the core curriculum developed by the Institute for the Promotion of Teaching Science and Technology, the instructional time recommended for students in the primary and secondary education level is 100 and 120 hours per semester, respectively. Instructional time for mathematics learning at primary and secondary education levels is recommended to be 150 hours per semester. The instructional period for each subject is flexible and based on the schools' preference. Generally, the length of instruction for each period is approximately 60 minutes in all grade levels, from the first primary grade through grade 12 (i.e., secondary grade 6).^{6,7}

Instructional Materials, Equipment, and Laboratories

Following the educational reform, the Institute for the Promotion of Teaching Science and Technology developed the core curriculum in mathematics and science for basic education. After the completion of the core curriculum for mathematics and science, other materials such as mathematics and science textbooks, teaching manuals, and workbooks for mathematics and science were developed as examples for schools to develop their own materials. By integrating details of the application of media and equipment into the institute's teaching manuals, teachers learned how to incorporate media and equipment into their teaching. The instructional materials and media are developed to suit students' backgrounds and to serve their local needs. Although the educational reform started 6 years ago, a lot of schools still use materials developed by the institute instead of developing their own materials.

Grade at Which Specialist Teachers for Mathematics and Science Are Introduced

In primary schools, teachers are responsible for instruction in all subjects. However, in some primary schools, teachers who are specialized in mathematics and science are assigned to teach mathematics and science in grades 1 to 6. For classes above primary grade 3, teachers are generally assigned to teach mathematics and science based on their training backgrounds. However, in some primary schools where there is a shortage of teaching personnel, one teacher may be assigned to teach more than one subject area. At the secondary education level, most teachers teach in subject areas relevant to their training backgrounds. The Ministry of Education provides professional development of teachers who are assigned to teach in subject areas other than those of their training backgrounds.

Use of Technology

Based on the Thai Basic Education Curriculum, computer literacy⁸ is mandated as one of the required skills in the work and career development subject area. According to the 2002 Basic Education Curriculum, every child is required to complete at least 12 credits of computer and technology classes before graduation from basic education (i.e., grade 12 or secondary education grade 6). Thai government policies and budget allocations continue

to focus on improving the infrastructure, developing educational content, and enabling universal access to the Internet.

The computer-to-student ratio has increased as a result of a project for children by the Ministry of Information and Communications Technology (ICT), which expanded computer distribution to schools in deprived areas in cooperation with the private sector. The modestly set targets in the National ICT for Education Master Plan for 2004–2006 were easily achieved in both primary and secondary schools under the Ministry of Education.⁹

Other governmental agencies taking part in providing online learning include the National Science and Technology Development Agency and the Thailand Graduate Institute of Science and Technology, which launched Learn Online to serve as a central repository for web-based courses from universities and organizations.

Since 2002, the Ministry of Education has implemented a number of projects to develop software, media, and learning content, along with technologies for education and use at the basic education level. Under the sponsorship of the School Net Project and the ministry, educational institutions and the private sector have developed multimedia centers, multimedia software, electronic books, and websites.

Teachers and Teacher Education

Education and Training for Fourth and Eighth Grade Mathematics and Science Teachers

Ideally, mathematics and science teachers must complete a bachelors' degree with pedagogy experience in the subject areas in the field that they teach. However, not all mathematics and science teachers meet the requirement. According to a study conducted by Siribunpitak,¹⁰ in the 2004 fiscal year, 93.6 percent of science teachers, and 94.6 percent of mathematics teachers in primary and secondary schools nationwide possess a bachelor's degree with pedagogy and teaching methods in the subject areas they teach. Thus, approximately 6 percent of the mathematics and science teachers do not meet the teaching qualification requirement. Under the current educational reform, upgrading the quality of and supports for teachers is being undertaken in the following programs of training.

- **Development of the 5-year professional development education program.** This program requires completion of a 5-year bachelor's degree, with the first 4 years dedicated to coursework and a final year devoted to teaching practice at an approved school. College graduates with a bachelor's degree in fields other than education must complete a 1-year graduate certificate program in education before being certified.
- **Professional development programs for a postgraduate certificate and master's degree in teaching.** Teachers holding a bachelor's degree in fields other than teaching are encouraged to undertake professional development programs leading to a postgraduate certificate or a master's degree in teaching.¹¹

In carrying out the teacher reform, several teachers' programs have been introduced to upgrade and support teachers' professional development.

- **Training activity to strengthen professional standards of teachers.** The training activities focus on improving teachers' academic capacity in subject areas, pedagogy methods, and personal and professional ethics.
- **Completion of a Bachelor of Education.** In accordance with the 1999 National Education Act, a professional teaching license is required for teachers and school directors, for which a bachelor's degree in education is a requirement. It is expected that all teachers will attain at least a bachelor's degree in education by the year 2007.¹²

Teacher Professional Development in Mathematics, Science, and Technology

One of the most important missions of the Institute for the Promotion of Teaching Science and Technology is the professional development of teachers and education personnel in science, mathematics, and technology. The institute provides countrywide, professional development teacher training programs to help teachers gain cutting-edge knowledge and capacity in using technology and planning lessons effectively. The training programs are delivered in a variety of means and channels, such as face-to-face, by correspondence, via satellite in collaboration with the Distance Learning Foundation and educational television, via the Internet, and at a symposium organized by various education agencies.¹³

Examinations and Assessments

National or Regional Examinations

National examinations are conducted by three major organizations: the Bureau of Education Testing (the Ministry of Education), the Office of National Education Testing (a public organization), and the Office of the Higher Education Commission.

The national test is administered by the Bureau of Education Testing under the Ministry of Education. The main purposes of national testing are to evaluate the country's overall educational quality, study the trends of educational development and indicators of the country's educational quality, and monitor and follow up on the quality of education. Additionally, schools are informed about the results of the testing for student development.

The national test emphasizes assessing students' knowledge, concepts, and analytical ability. It is designed to assess student achievement based on what students have been taught according to the curriculum guidelines. The tests assess student achievement in four grade levels: primary education, grade 3; primary education, grade 6; secondary education, grade 3; and secondary education, grade 6 (equivalent to grade 12). The details of the subject areas to be assessed are as follows.

- *Primary education, grades 3 and 6 (eight subject areas):* Thai, English, mathematics, science; social studies, work and careers, problem solving, and general characteristic qualifications
- *Secondary education, grade 3 (five subject areas):* Thai; English; mathematics; science; and social studies, religions, and cultures

- *Secondary education, grade 6 (seven subject areas):* Thai; English; mathematics; chemistry; biology; physics; and social studies, religions, and cultures.

Ordinary national education tests are administered by the Office of National Education Testing. As an independent public organization, the Office of National Education Testing has the responsibility of informing the school, government, and public about the test results based on the basic education curriculum standards. The tests are designed to assess student achievement in primary education, grade 6; secondary education, grade 3; and secondary education, grade 6. Details of the subject areas to be assessed are as follows.

- *Primary education, grade 6 (three subject areas):* Thai, mathematics, and science
- *Secondary education, grade 3 (five subject areas):* Thai; mathematics; science; social studies, religions, and cultures; and English
- *Secondary education, grade 6 (eight subject areas):* Thai; mathematics; science; social studies, religions, and cultures; foreign language; health and physical education; the arts; and work and careers.

Tests in health and physical education, the arts, and work and careers may be waived for students at secondary education, grade 6.

Advanced national education tests are administered by the Office of the Higher Education Commission. These tests are designed to select students for entrance into higher education institutions. The subject areas for the national entrance examination are Thai; mathematics; science; social studies, religions, and cultures; and foreign language.

Monitoring Individual Student Progress

The assessments and evaluations to monitor individual student progress are designed by teachers who teach the subjects to their students. The results of the evaluation are used to monitor and follow up on students' academic progress and enhance students' development to their full potential.

Grading and scoring of students' tests are conducted by subject-specific teachers. Criteria for scoring in each individual subject matter are developed by these teachers.

The purpose of the testing developed and administered by schools in Thailand is to assess student achievement annually. Information from the assessment is used as a guideline to improve the quality of teachers' performance as well as students' learning outcomes in order to align them with the educational standards required by the curriculum.

Grade Promotion and Retention Policies

Student achievement scores on the tests developed to monitor individual student progress also are used as information for making decisions about whether the student achieves the required educational standards and is eligible to study in the next level or fails to meet the standards and is retained to study at the same level. If a student does not pass the assessment criteria, the school is responsible for providing remedial teaching and offering to retest the student.

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Tunisia

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Introduction

Overview of Education System

Education is “a fundamental right guaranteed to all Tunisians regardless of gender, social origin, skin colour or religion.”¹ Recognized by the constitution, this right is asserted by the Law of Educational Orientation.² Article 4 of this law stipulates that “the State provides free education to all those who are of school age, and gives all students an equal chance of enjoying this right...”³

Consequently, education is a public service managed by the state through the Ministry of Education and Training. This does not exclude the existence of private establishments practicing within the framework of the national education system. The educational objectives, teaching programs, and textbooks are established nationally.

As for the disciplines, the programs and the curriculum of mathematics and of science (direction of the programs) are defined by the ministry, and all school and public establishments must implement them.

According to the law, school education takes place in two stages: basic education and secondary education. **Basic education** is 9 years, compulsory for ages 6 to 16, and divided into two cycles.

- The first cycle, which is in primary schools, is 6 years and includes children from ages 6 to 12.
- The second cycle or preparatory cycle, which is in lower secondary schools, is 3 years and includes children from ages 13 to 16.

Secondary education occurs in upper secondary schools and is 4 years.

Preschool education, for ages 3 to 6, takes place in establishments and specialized areas. The goals of preschool education are to socialize children and prepare them for school education. The last year of preschool education constitutes a preparatory year for the primary cycle, which is integrated into basic education. Although noncompulsory, the government has decided to generalize it, entrusting this responsibility to the Ministry of

Education and Training. Preschool education prepares the child for community life and allows for the development of oral communication, the senses, psychomotor capacities, and the healthy perception of the body.

There have been three major reforms of the Tunisian education system since independence in 1956. The latest reform was in 2002. Besides the modernization of the school, this reform focused on providing a quality education to everyone and preparing the students to play an active role in society. The reform concerns all aspects of education: programs, teacher training, educational methods, evaluation, school management, and school life.

Article 52 of the Education Act defines the objectives of teaching mathematics and science.⁴ As a result, new programs were set up. Student performance is expected to improve as a direct outcome of these changes. The next TIMSS and PISA studies will be suitable occasions to verify if these expectations were satisfied.

Also, following Tunisia's participation in TIMSS 1999 and 2003, and in light of the results obtained by its students, it was decided to introduce the teaching of physics in secondary schools in grade 7.

Language and Population

The official national language of the country is Arabic. It also is the language of instruction for all subjects included in basic education. However, in secondary school, all science subjects are taught in French.

Along with Arabic, French occupies, for historic reasons, an important place. Students begin learning French in grade 3. English is the second foreign language taught, beginning in grade 6. The teaching of mathematics and science in grades 4 and 8 is in Arabic.

Emphasis on Mathematics and Science

At the end of the first year of secondary education, students are directed to specialized subject areas, such as in science and technology. Parents also tend to urge their children to choose these areas.

The policy of the government aims to have 70 percent of students choose to specialize in science and technological areas and to increase the opportunities in these areas both in secondary school and at the university level.

The Mathematics Curriculum in Primary and Lower Secondary Grades

Summary of National Curriculum Guides for Mathematics Through Eighth Grade

Exhibit 1 shows the mathematics curriculum for **grades 1–4** in basic education in Tunisia. The **processes** in mathematics education in these grades focuses on knowing facts and procedures using whole numbers; understanding the meaning of addition, subtraction, and multiplication; and solving problems related to daily life using numbers, measurement, and geometrical figures.

Exhibit 1 Mathematics Curriculum for Grades 1 to 4 in Tunisia

Contents	Grades 1–2
Numbers	Read, write, represent, expand, and compare whole numbers from 0 to 999 Compute with whole numbers from 0 to 999 using addition and subtraction Identify sets of numbers according to common properties Use mental computing
Geometry	Identify the relative position of objects in space, lines, and closed curves Identify and draw polygons according to the number of their sides
Measurement	Use whole numbers to measure length, capacity, mass, time, and money
Algebra	Identify a common property of the collection of elements and classify objects according to common properties and count a collection Use shapes, patterns, and models to classify objects or find an unknown quantity
Contents	Grades 3–4
Numbers	Read, write, represent, expand, and compare whole numbers from 0 to 999,999 Compute with whole numbers using addition, subtraction, and multiplication Divide numbers within multiplication tables and find the quotient and remainder in the Euclidean division of two integers Use mental computing
Geometry	Use geometric diagrams Identify and draw acute, obtuse, and right angles; perpendicular and parallel lines; and squares and rectangles using rulers and set squares
Measurement	Use whole numbers to measure length, capacity, mass, time, and money Find the perimeter and the area of squares and rectangles and figures made up of squares and rectangles and make estimates of an area
Algebra	Use shapes or models to find an unknown quantity
Data	Read, select, and organize using tabular and graphical methods

Exhibit 2 shows the mathematics curriculum for **grades 5–6** in basic education. The **processes** in mathematics education in grades 5–6 focus on the following: knowing facts and procedures using whole decimal and rational numbers; understanding the meaning of the four operations; reasoning about shapes; solving problems using numbers, proportionality, measurement, and the properties of two- and three-dimensional figures; and providing a link between everyday language and mathematical language.

Exhibit 2 Mathematics Curriculum for Grades 5 to 6 in Tunisia

Contents	Grades 5–6
Numbers	Compute with whole and decimal numbers using the four operations Compute with rational numbers using addition, subtraction, and multiplication Compute with equivalent fractions, scale, and percentage Identify and compare whole, decimal, and rational numbers Use mental computing

Exhibit 2 Mathematics Curriculum for Grades 5 to 6 in Tunisia (Continued)

Contents	Grades 5–6
Geometry	Use geometric diagrams Identify and draw acute, obtuse, and right angles; perpendicular and parallel lines; squares and rectangles; circles; and symmetric figures to a given line of symmetry Construct a 2-D representation of a 3-D solid Construct perpendicular and parallel lines Construct triangles, squares, and rectangles according to their geometrical properties Identify complementary and supplementary angles
Measurement	Measure length, area, angles, capacity, mass, time, money, and velocity Find the perimeter and the area of figures made up of squares, rectangles, triangles, trapeziums, and circles
Algebra	Use shapes or models to find an unknown quantity
Data	Read, classify, and select data from tables or shapes Organize and represent data in bar graphs, pictograms, and diagrams

The **processes** in mathematics education in **grades 7–8** focus on the following: knowing facts and procedures using integers, decimal, and rational numbers; understanding numerical and geometrical concepts; reasoning using deduction and induction; working mathematically; solving problems using numbers, proportionality, measurement, and properties of two- and three-dimensional figures; and using mathematical language. Exhibit 3 shows the mathematics curriculum for grades 7–8 in basic education.

Exhibit 3 Mathematics Curriculum for Grades 7 to 8 in Tunisia

Contents	Grades 7–8
Numbers	Compute with integers, decimals, and rational numbers using the four operations Use prime numbers, common factors, compute multiples, compute powers of numbers Find the square root using calculator Compare, make estimates, and round off numbers
Geometry	Identify, measure, compare, and construct angles involving adjacent angles, vertically opposite angles, complementary and supplementary angles, angle bisectors, alternate angles, corresponding angles, interior angles between parallel lines, and angles of special triangles or special quadrilaterals Find the distance between two points, from a point to a line, and between two parallel lines Recognize and identify congruent triangles Identify and construct special triangles, special quadrilaterals, and circles according to their properties Construct a symmetric figure to a given line of symmetry or a given point Find and use Cartesian coordinates of a point in two dimensions
Measurement	Calculate length, capacity, mass, time and money, and velocity Find the perimeter, area, or volume of figures made up of squares, rectangles, triangles, trapeziums, circles, cubes, prisms, cylinders, pyramids, cones, and spheres using geometrical properties, scale, or proportionality Measure angles using geometrical properties

Exhibit 3 Mathematics Curriculum for Grades 7 to 8 in Tunisia (Continued)

Contents	Grades 7–8
Algebra	Use letters to represent numbers Compute with simple algebraic expressions Solve simple linear equations
Data	Collect, classify, and summarize data in tabular ways and statistical diagrams Read, interpret, and make predictions using statistical data and statistical diagrams

The Science Curriculum in Primary and Lower Secondary Grades

Summary of National Curriculum Guides for Science Through Eighth Grade

The learning and teaching processes in **grades 1–6** emphasize the characterization and identification of concepts. In *earth science and biology*, students should be able to characterize living organisms according to their nutrition and respiration. They also should be able to characterize the different methods of reproduction according to the living organisms. In addition, they should be able to identify some diseases and their prevention methods. Concerning *the environment*, they should recognize some elements that disrupt the environmental balance and mention some means to protect the environment. In *physics and chemistry*, students are expected to recognize devices that can be used to measure time. They also are expected to recognize the different states of matter and the conditions under which matter undergoes a change of state. In addition, they should be able to recognize the physical properties of air and also identify the different types of energy, as well as the natural sources of energy.

In regard to the **processes**, in **grades 7–8**, students are expected to develop the capacity to do the following: understand chemical and physical concepts, understand relationships between organisms and functions of systems, observe and do experiments, reason and draw conclusions, work scientifically, and solve problems related to their environment.

In regard to the **content** of the science curriculum, in grades 7 and 8, students are expected to investigate and understand basic principles and concepts related to the nature of the following.

- Matter, including characteristics of types of matter, based on chemical properties (solids, liquids, and gases) and physical properties (density and concentration) and symbols of some basic elements and simple reactions
- Light, including reflection, refraction, and spectrum
- Electricity and magnetism, including electric current and circuits and motors and generators
- Environmental elements and the identification of the relationships between these elements
- The life cycles of plants and animals including reproduction
- The mechanisms of photosynthesis and respiration for plants
- The mechanisms of the nervous, respiratory, and circulatory human systems.

Instruction for Mathematics and Science in Primary and Lower Secondary Grades

Instructional Time

The latest reform of the Tunisian education system led to a curriculum that emphasizes science, languages, and vocational training, as well as integrates the National Institute of Information and Communications Technology at all educational levels in order to promote reasoning, thinking, and problem-solving skills and the mastery of information and communication technology. Exhibit 4 below shows the mathematics and science instructional time per week in detail.

Exhibit 4 Instructional Time in Grades 1–9 in Tunisia

Subject	Grade					
	1	2	3 and 4	5 and 6	7	8 and 9
Mathematics	5 hours	5 hours	5 hours	5 hours	4 hours	4 hours
Science	1 hour	1 hour	2 hours	2 hours	1.5 hour	1.5 hours
Technological Education	1 hour	1 hour	1 hour	1.5 hours	1 hour	1 hour
Computational Education					1 hour	1 hour
Physics					1.5 hours	1.5 hours
Total Instructional Time	20 hours	20 hours	25 hours	30 hours	32 hours	33 hours
Ratio	35%	35%	32%	28%	28%	27%

Source: Tunisian Ministry of Education and Training. (2006). *Education statistics*. Tunis: Author.

Instructional Materials, Equipment, and Laboratories

Primary schools do not have science laboratories at their disposal. However, they do have the minimum required equipment for the teaching of science. Lower secondary schools have well-equipped science and physics laboratories.

Grade at Which Specialist Teachers for Mathematics and Science Are Introduced

Since 2007–2008, a primary school teacher teaches all subjects in grades 1 to 6, while a lower secondary school teacher can teach only mathematics, chemical and physical sciences, or environmental sciences.

Teachers and Teacher Education

Education and Training for Fourth and Eighth Grade Mathematics and Science Teachers

In Tunisia, primary school teachers are managed by the Primary Education Department of the Ministry of Education and Training while secondary school teachers are managed by the Secondary Education Department of the Ministry of Education and Training.

Since 2007–2008, to be recruited as a primary teacher, one must first have an academic education (3 years) that leads to a license. Students who have obtained a university license and want to become primary school teachers also have to pass a written examination proposed by the Ministry of Education and Training. If they succeed, they have to follow a 1-year training program in an academic institute.

To be recruited as a secondary school teacher, it is required that teachers have an academic education (3 or 4 years at university) that leads to a license. Students who have a license in mathematics and want to become mathematics teachers have to pass a written examination proposed by the Ministry of Education and Training. After the training, students pass an oral examination. Those who succeed in the oral examination are recruited as lower and upper secondary school teachers. Then they are trained during 3 weeks (50 hours) in summer school, where the program focuses on educational subjects and information and communication technology. The teacher training (theoretical and practical) is monitored by the inspectors of mathematics.

Teacher Professional Development in Mathematics, Science, and Technology

Since 2003, the Tunisian Ministry of Education and Training has been engaged in a reform of teacher professional development training.⁵ As a result, the Training Department set up a new program that aims basically to improve the quality of the educational outcome through innovating objectives, content, and methodology.

The main objectives of this reform are to provide teachers with more autonomy and enhance their role in the educational process. This framework is intended to provide teachers with opportunities to develop reflective skills, consolidate their mathematical knowledge, be well informed and aware of the new pedagogical and didactical methods, learn by themselves and have access to effective instructional and technological tools, work with other teachers, and participate with the educational staff in improving the role of the school in society.

Mathematics professional development is compulsory for all primary school teachers and is organized throughout the entire year. It represents 30 percent of the total teacher professional development training and is staffed by primary education inspectors. The framework focuses on mastering disciplinary concepts linked with the curriculum of the schools; problem-solving strategies, especially for problems related to daily-life situations; assessment procedures; and the teaching-learning process in mathematics. Training concerning pedagogical approaches and the use of technology is integrated into the general training.

Teacher professional development training for secondary school teachers is organized during the entire year and staffed by inspectors. Every 15 weeks, one day (8 hours) is reserved for secondary teachers' training. Every teacher has to choose, among the 15 days proposed, 6 days of training according to his or her needs. The expectation is that every teacher has to attend 6 days of teacher professional development training yearly. In addition, a 1 to 3 week program for teachers is offered in summer school for teachers who are interested in specific training (discipline, information and communication technology, pedagogy, and didactics). A curriculum that serves as a guideline is produced every year and includes three components: discipline subjects, pedagogical and didactical subjects, and technology subjects. The training in mathematics focuses on topics that are connected to changes in the curriculum and textbooks. The goal of this training is to update and increase the depth of knowledge of teachers in these topics.

Examinations and Assessments

National or Regional Examinations

In grade 4, there is a regional examination for all students that is compulsory and is used for promotion. The decision to implement this examination occurred in 2007. Students may take an optional examination in grade 6. The outstanding students who do well on this examination continue their studies in a lower secondary special school. Similarly, after completing basic education (grades 1–9), students may take an optional examination in grade 9. Success on this examination results in a certificate allowing students to continue their studies in an upper secondary special school for outstanding students.

At the end of upper secondary education (grade 13), students take the National Baccalaureate Examination (*Examen National du Baccalauréat*). The content consists of an average of six subjects, each of which is assigned a weight depending on the student's study stream. Students who pass the baccalaureate are allowed to enter the university, while those who do not pass enter the workforce or study at a private school.⁶

Suggested Readings

Ministry of Education and Training:
www.edunet.tn

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Turkey

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Introduction

Overview of Education System

According to the Basic Law of Education, the Ministry of National Education is responsible for planning, programming, advancing, monitoring, and inspecting all educational and training services and activities.¹

In the Turkish national education system, formal education includes preprimary, primary, secondary, and higher education. Primary education is free of charge and compulsory for all citizens.

The objective of **preprimary education**, ages 3–6, is to ensure that children develop physically, mentally, and emotionally; acquire good habits; and are prepared for primary education. Children in preprimary education who come from disadvantaged backgrounds are provided with a common environment, and teachers ensure that they speak Turkish correctly.²

Primary education is 8 years long and for ages 6–14. The goals of primary education are to enable students to acquire the basic knowledge, skills, and attitudes necessary to prepare for higher education and for life. Graduates receive primary education diplomas. There are 34,093 primary schools, of which 866 are private, and 10,870,570 students, including 5,678,872 boys and 5,193,698 girls.³ According to the data gathered from the Turkish Statistical Institute in the last census, the percentage of females in the total population who are 14 years olds is 48.85, and the percentage of males of the same age is 51.15. Additionally, the figures are almost the same for the total population ages 6–14, with 48.71 percent females and 51.29 percent males.⁴ These indicators are consistent with the difference in the distribution of females (46%) and males (54%) in TIMSS 2007.⁵

Secondary education, which covers general, vocational, and technical high schools, is a minimum of 4 years and for ages 15–18. After completing primary education, any student has the right to attend secondary education, but it is optional. In Turkey, there are seven different types of general high schools (focused on science education, learning foreign languages, etc.) and 10 different types of vocational and technical high schools

(focused on professions, such as the tourism industry). Although the curriculum differs according to the specific purposes of each type of school, the goal of secondary education is to give students a common, minimum, overall knowledge; familiarize them with the problems of the individual and society and how to seek solutions; ensure that students gain awareness that will contribute to the socioeconomic and cultural development of the country; and prepare them for higher education, a profession, life, and employment in line with their interests and aptitudes.

There are various public and private institutions related to mathematics and science in Turkey and two main funding agencies. The first is the Scientific and Technological Research Council, an autonomous institution that was established in 1963. Its mission is to advance science and technology, conduct research, and support Turkish researchers. This council also is responsible for promoting, developing, organizing, conducting, and coordinating research and development in line with national priorities and targets. It acts as an advisory agency to the Turkish government on science and research issues and reports directly to the prime minister.⁶

Another funding agency is the Turkish Intelligence Foundation. The main goals of this foundation are to create individuals with cognitive, perceptive, analytical, decision-making and problem-solving skills who can adapt to the ever-changing world and have a flair for the arts.⁷

The development of a curriculum is based on institutional cooperation and the participation of various institutions and bodies related to education. The curriculum development process starts with a needs assessment, involving students, teachers, trainers, parents, and scientists. On the basis of the data gathered from the needs assessment, a draft curriculum is developed by the Curriculum Development Commission. The drafts are discussed by the Board of Education, which is an advisory and decision-making body of the ministry. After finalization by the board, the curriculum is submitted to the ministry for approval. Once approved, the curriculum is put into practice. This process is valid for all courses including mathematics and science.

Recently, the curriculum of the primary and secondary schools was revised in 2004 and piloted in 2005. The effects of the new curriculum are expected to be seen in the results of TIMSS 2011. In the 2005–2006 school year, the new curriculum for grades 1–5 was put into practice in all primary schools. In the same academic year, the new curriculum for grade 6 was piloted in schools and put into practice in all primary schools in the 2006–2007 school year. The piloting of the new curriculum for grade 7 also took place during the 2006–2007 school year, with its implementation occurring the following academic year. The new curriculum for grade 8 is being piloted in the 2007–2008 school year and will be put into practice during the 2008–2009 school year.

Language and Population

According to the National Constitution, the official language in Turkey is Turkish. Therefore, in primary and secondary education, all instruction is offered in Turkish.

Emphasis on Mathematics and Science

Although there is no explicit emphasis on mathematics or science, basic competencies in mathematics and science and related educational policies have been promoted since the revision of primary and secondary school curricula in 2005.

Among the national policies, science high schools play an important role in encouraging students to pursue careers in mathematics, science, and technology. There are 151 science high schools in Turkey—70 of them are public and 81 of them are private schools. The goal of science high school is to give students the necessary background in mathematics and science so they will be prepared to enter the engineering and technical faculties of universities and can pursue careers in mathematics and science. Students who want to go to science high schools have to pass the Entrance Examination for Secondary Schools at the end of eighth grade. Mathematics and science are given considerably more importance in the curriculum of science high schools compared to the curriculum of other high schools.

The Mathematics Curriculum in Primary and Lower Secondary Grades

Summary of National Curriculum Guides for Mathematics Through Eighth Grade

The new mathematics curriculum follows a conceptual approach that uses students' experiences to help them comprehend and consider mathematics abstractly. Through projects and specific homework, this approach enables students to express their individual differences and abilities. Students research, discover, and discuss their solutions. The goal is to develop students' psychomotor abilities by using different materials for different activities.

The primary school mathematics curriculum has four learning strands that emphasize skills, understanding, and attitudes. The four mathematics learning strands for **grades 1–5** include numbers, geometry, data, and measurement.⁸

- *Numbers*: use numbers and digits; develop estimation and operation abilities by understanding the four arithmetical operations; associate fractions, percentages, and decimal fractions; and determine relations within patterns and apply this information to problem situations.
- *Geometry*: develop spatial abilities, determine relationships between geometric shapes and objects, decorate with planar shapes, understand and use symmetry, and use geometry tools and materials.
- *Data*: data gathering and organizing and analyzing of data (probability is taught beginning in the fourth grade).⁹
- *Measurement*: estimation abilities and the development of concepts of measurement.

The five mathematics learning strands for **grade 6** include numbers, geometry, measurement, probability and statistics, and algebra.

- *Numbers*: natural numbers, integers, operations on integers, multiples and factors, fractions, decimals, percentages, rate and ratio, and sets.

- *Geometry*: lines, line segments, and rays; angles; polygons; congruency and similarity; transformation geometry; patterns and ornaments; and geometric shapes.
- *Measurement*: angles, length, area, time, volume, and liquids.
- *Probability and statistics*: probable conditions, main concepts of probability, types of events, preparing survey questions and collecting data, tables and graphics, and measures of central tendency and dispersion.
- *Algebra*: patterns and relations, algebraic expressions, and equality and equations.

The five mathematics learning strands for **grade 7** include numbers, geometry, measurement, probability and statistics, and algebra.

- *Numbers*: operations using integers and rational numbers, rates and ratios, and consumer arithmetic.
- *Geometry*: lines and angles, polygons, congruency and similarity, circles and circular area, geometric shapes, transformation geometry, and patterns and ornaments.
- *Measurement*: measuring angles, areas of quadrilaterals, perimeter of a circle and an arch length, area of a circle and sector, surface areas of geometric shapes, and volume of geometric shapes.
- *Probability and statistics*: probable conditions, types of events, types of probability, tables and graphics, and measures of central tendency and dispersion.
- *Algebra*: patterns and relations, algebraic expressions, and equations.

The **eighth grade** mathematics curriculum in the 2007–2008 school year includes the following learning strands: real numbers, algebraic expressions and equations, proportional line segments and similar triangles, permutation and probability, measures of surface areas and volumes, and mathematical systems.

The Science Curriculum in Primary and Lower Secondary Grades

Summary of National Curriculum Guides for Science Through Eighth Grade

In Turkey, science and technology is included as a compulsory course from grades 1–8. In grades 1–3, this subject is taught by classroom teachers and is called life study. In grades 4–8, it is called science and technology, and it is taught by classroom teachers in grades 4 and 5 and by science teachers in grades 6–8.

The new Turkish science and technology curriculum has seven learning strands. These are physical processes, life and living beings, matter and change, the Earth and the universe, science process skills, science-technology-society-environment, and attitudes and values.¹⁰ While the first four represent content areas, the remaining three are interwoven throughout the grades. Although they are not included as separate units, they are visible in all content area units. This approach clearly indicates the intent of having students engaged in student-centered activities while learning content. Learning by doing is seen as a central pillar of the new curriculum.

One of the features of the new curriculum is that outcomes for science process skills, science-technology-society-environment learning, and attitudes and values are identified and defined in the curriculum for the first time for the appropriate level and grade. The related outcomes increasingly have become visible in school science contexts through the curriculum materials and textbooks.¹¹

For the first time in Turkish primary education, a technology component is being integrated into science education. It is considered necessary and inevitable to understand both the nature of science and technology during compulsory formal education. The structure of the curriculum was revised based on the constructivist approach, so that students may bring their daily life experiences to the classroom and can take their school experiences into the real world. In order to realize this, several activities have been proposed that can incorporate many related curriculum outcomes into technology understanding.

Traditionally, science courses in primary education had been called “science knowledge”. However, this leads students and people to think that science is made up of only certain knowledge. In order to make the curriculum reform more meaningful, a name change was instituted to reflect the incorporation of technology. As a result, it is now called “science and technology”. It also should be mentioned that there is a separate course, design and technology, which is aligned with the science and technology curriculum. This 2-hour weekly course will give students more opportunities to participate in technology activities and applications.¹²

Instruction for Mathematics and Science in Primary and Lower Secondary Grades

Instructional Time

The instructional time per week is decided by the ministry. At the primary level, the total number of hours is 20 hours per week. Thirteen percent of weekly instructional time is devoted to mathematics, and 10 percent is devoted to science and technology. With the current reform efforts, in primary education, a significant improvement was made in the weekly science course hours. Instructional time has increased to 4 hours per week.

Instructional Materials, Equipment, and Laboratories

Instructional materials are used in achieving the goals of the curriculum. Books, periodicals, and other instructional materials, prepared by either the ministry or the private sector, are reviewed and evaluated by the ministry in line with specified evaluation criteria within the scope of the provisions of the Regulation on the Review of the Instructional Material in return for a specified fee. Authors’ books or books from publishing houses are examined and the necessary procedures are applied before submitting the books to the Board of Education. Those books that are approved by the board are used by schools following their announcement in the ministry’s *Periodic Notification Bulletin*.¹³

Grade at Which Specialist Teachers for Mathematics and Science Are Introduced

In the Turkish education system, schools have subject area specialist teachers for mathematics and science beginning in the sixth grade.

Use of Technology

The Ministry of National Education uses technology in the following ways.

- *Information and communication technology at schools:* 14,221 primary schools have 15,606 computer laboratories, with 357,380 computers available for students' use, and 18,499 schools have an Internet connection.
- *e-school:* In this system, parents, students, teachers, school administrators, educational specialists, etc., can interact with each other on the Internet. For example, students and parents can see the report cards for each course at the end of each semester, parents can interact with their child's teachers, and teachers can give students homework.
- *e-graduate:* In this system, the ministry monitors alumni after they graduated from school and checks on their employment.
- *Ilis:* In this system, all teachers' data at primary and secondary levels are gathered on a daily bases and also can be used for administrative purposes.
- *Intel- and Microsoft-supported projects:* Skool, Wimax, and laptops for teachers.

Teachers and Teacher Education

Education and Training for Fourth and Eighth Grade Mathematics and Science Teachers

After considering the teacher requirements to teach 8 years of primary education implemented by Law Number 4306, teacher training programs have been reorganized in order to meet the short- and long-term teacher requirements in primary education. In terms of content and length of training, the new reorganization includes the following topics.¹⁴

- A 4-year undergraduate education for preprimary and primary education teachers
- A 4-year undergraduate education for both primary and secondary education teachers for common subject areas, including foreign languages, music, drawing, physical education, special education, and computer and technology teaching.

Primary school mathematics and science teachers are required to get a Bachelor of Arts degree from a university with related departments in education and to obtain the necessary points from the Public Servant Selection Examination. After they meet these requirements, they are chosen according to the points received on this examination.

Teacher Professional Development in Mathematics, Science, and Technology

In order to provide teacher professional development, the ministry collaborates with universities, the private sector, and other related public institutions such as the Scientific and Technological Research Council; Atatürk Supreme Council of Culture, Language, and History; and the Foreign Language Training Center for Government Officers to

provide financial and human resources. In order to decide what types of professional development to provide, the needs of the teachers and school administrators and new developments in the field of education are taken into consideration. The professional development department of the ministry conducts the needs assessment, selects the high priority topics, and develops a professional development plan on a yearly basis. This plan is announced to the staff, including teachers and school administrators, on the web page of the ministry, and official documents are sent by the ministry to the schools. In 2008, 730 training programs are planned in the following categories: computer and other technology-assisted education practices, using computers in education, teaching and management services, foreign language education programs, induction programs for newly recruited teachers, pedagogical formation courses, courses for promotion in career development, training of trainers in the programs, master's and doctoral programs in the field of public and educational administration in the Public Administration Institute for Turkey and the Middle East, education activities in foreign countries, and training programs for teachers for students with disabilities. In addition to the above-mentioned programs, teachers and school administrators have the opportunity to participate in some programs via the Internet. The registration procedures are conducted by the teacher professional development department via the Internet.

Examinations and Assessments

National or Regional Examinations

The ministry is responsible for the assessment of student performance in Turkey. The goal of the national assessment studies is to assess the educational achievement of students in a variety of subject areas at several age and grade levels and identify trends in achievement levels over specified periods of time.

One national assessment is the Student Selection Examination for secondary educational institutions. This examination is held when students transition from primary to secondary education. Eighth grade students are the target group to be placed at selected secondary educational institutions including Anatolian high schools (where the curriculum places more emphasis on learning English and mathematics), science high schools (where the curriculum places more emphasis on learning science), and Anatolian teachers high schools (where the curriculum places more emphasis on learning English and pedagogy). However, this examination will take place for the last time in 2008 and will be replaced by the Student Achievement Level Examination, which will be given at the end of sixth, seventh, and eighth grades. According to the total score calculated from the results of these three examinations, students are placed in one of the specified secondary schools mentioned previously. The results of these examinations are expected to constitute the greatest data source for showing the knowledge and skills of students in primary education at a national level.¹⁵

Another national assessment study is the Student Achievement Assessment Test. It is conducted for the purpose of quality control in primary education. A randomly selected sample of fourth, fifth, sixth, seventh, and eighth grade students are tested in the Turkish

language, mathematics, science, social science, English, and computer literacy. This test has been conducted by the Ministry of National Education, Education Research, and Development Directorate every 3 years since 1992. The results are used to evaluate the academic achievement and the intellectual capabilities of students and develop new policies for better primary education. In 2005, 154,000 students from 829 schools formed the nationwide sample who took the latest Student Achievement Assessment Test.¹⁶

In addition to the standardized achievement tests, questionnaires are used that allow for the evaluation of student achievement in several ways.

Monitoring Individual Student Progress

As mentioned earlier, all primary and secondary school students are being monitored on a semester basis using the e-school system. Through this system, all students' personal records, interests, hobbies, books read, and records, etc., are kept by classroom teachers.

In addition, the new curriculum adopts a multilevel, multifaceted measurement and assessment approach to student learning. Teachers are urged to use more formative learning assessment and measurement techniques rather than the usual paper and pencil tests. Many alternative measurement methods and techniques are used, including the development of student portfolios, group activities, and peer evaluations. The idea is that students can learn more meaningfully when they are motivated and engaged in their own learning. Thus, the overall teaching strategy takes advantage of all methods and techniques during all stages of teaching and learning.¹⁷

Grade Promotion and Retention Policies

Students who finish eighth grade receive a document attached to their primary school diploma certifying students' tendencies, abilities, and interests. In general, if a student fails to reach the classroom level at the end of the first semester in primary school, teachers, the school administrator, the school counselor, and the student's parents hold a meeting to decide on the necessary precautions to take to enable the student to reach the classroom level by the end of the second semester. In spite of all the precautions taken, if the student fails to reach the classroom level at the end of the school year, the school council, which includes the school counselor, the student's teacher, and the school administrator, decide whether this student should pass or repeat the class. After this decision is made, the parents of the student are informed.¹⁸

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United States

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Introduction

Overview of Education System

In the United States, approximately 88 percent of U.S. elementary and secondary school students attend public schools. The remaining students attend private schools or are homeschooled. The public schools are primarily administered and funded by 14,200 local school districts and their state education agencies that operate in the 50 states and the District of Columbia. The bulk of public school revenues come from state funds and local property taxes, and, therefore, local school districts and state education agencies exercise greater control over schools than the federal government. About 9 percent of education funding comes from federal sources.

The U.S. Department of Education's mission focuses on distributing and monitoring funding for specific programs created by Congress, collecting data and disseminating research, focusing national attention on key educational issues, prohibiting discrimination, ensuring equal access to education, and establishing policies on federal financial aid for higher education.¹ At the state level, each state's department of education is responsible for the distribution of federal and state resources, implementing federal and state programs, assuring compliance with federal and state laws, providing technical assistance, establishing policies related to curriculum and instruction, overseeing the teacher certification process, and implementing student assessments for accountability.

Subject area curriculum frameworks are the responsibility of state education agencies and local school districts. Local school districts and, sometimes, individual schools decide what curricula are actually taught. States are responsible for developing curriculum frameworks in core subject areas and implementing accountability systems tied to curriculum standards.

State departments of education or local school districts may organize subject-specific conferences and training opportunities to allow educators to collaborate on developing curriculum or instructional materials. Additionally, national professional organizations provide opportunities for educators and curriculum specialists from different districts

and states to enhance their skills at regional conferences and workshops. In developing and revising curriculum frameworks, state departments of education and local districts typically rely on committees of subject specialists to collaboratively review and make decisions about the curriculum.

In the United States, public education refers to the system by which federal, state and local governments provide the funding and oversight of free and compulsory public schools for all children from the ages of 5 or 6 to 16 or 18, depending on the state. Publicly funded education ends when a student graduates from high school or finishes grade 12, usually at age 18. (The age at which students are permitted to leave school before graduation varies among the states.) Postsecondary education is not free, though federal grants and student loan programs exist to which students may apply for assistance. Public universities and colleges are funded by state governments.

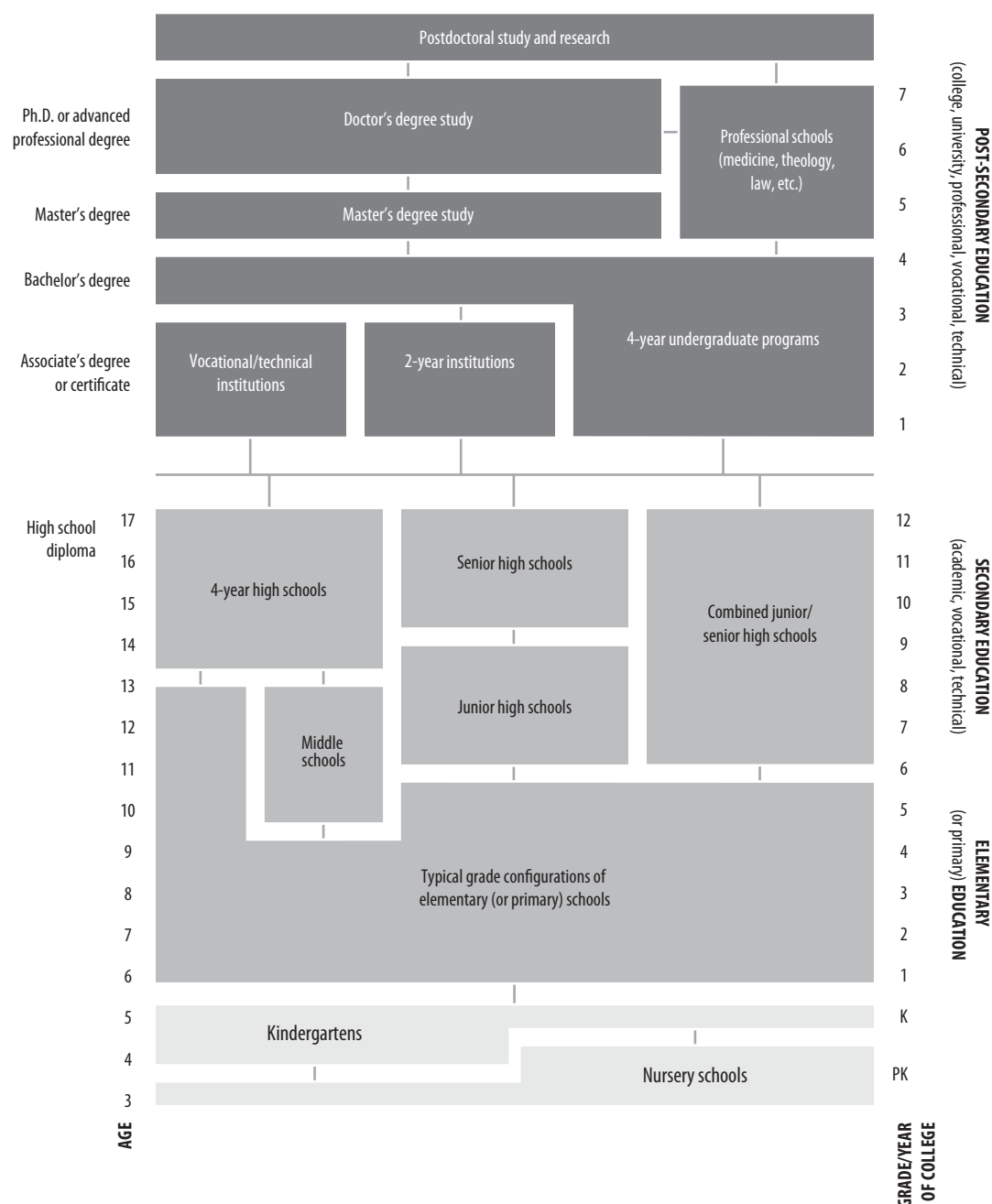
Outside the public K–12 education system, private schools comprise a sizeable segment of U.S. schools. In 2001–2002, 10 percent of U.S. students attended private schools, of which about 77 percent had religious affiliations.² In 2003, 2.2 percent of students were homeschooled.³ Students are considered to be homeschooled if their parents report them as being schooled at home instead of at a public or private school.⁴

Most preschools are private enterprises, and they vary widely in the programs they offer. Although preschool is widespread, it is not typically included in publicly funded education. Some states support programs for 4-year-olds, and most are equipped to provide preschool education to some children with disabilities or learning challenges. The federal Head Start program provides free preschool education to children from economically disadvantaged backgrounds.

School districts organize grades into elementary schools (kindergarten and grades 1–4, or 1–5), middle schools (grades 5–8, 6–8, or 7–8, sometimes called intermediate or junior high schools), and high schools (typically, grades 9–12). At age 5 or 6, a child will enter kindergarten and will be promoted to first grade the following year, continuing until fifth or sixth grade. In the lower grades of elementary school, students usually have one teacher for all core academic subjects, including mathematics and science, and remain with the same peer group for the full year. Middle schools usually encompass grades 6–8, though some may include grade 5 or only grades 7 and 8. Students move to different classrooms throughout the day, have a different teacher for each subject, and may or may not stay with the same peer group for different classes. In many U.S. middle schools, students are offered some choice in selecting elective courses outside the core academic subjects.

In high school, students in grades 9–12 continue to have more choices in their academic program. Accelerated academic pathways and career and technical education options often are offered, and more electives are available to accommodate students' interests. Grades are recorded in student transcripts, which are used to document completion of graduation requirements and for competitive admission to higher education. After graduation from high school, students continuing their education enroll in public or private universities or colleges, community colleges, or vocational or technical schools (see Exhibit 1).

Exhibit 1 The Structure of Education in the United States



Note: Exhibit is not intended to show relative number of institutions nor relative size of enrollment for the different levels of education. Exhibit reflects typical patterns of progression rather than all possible variations. Adult education programs, while not separately delineated above, may provide instruction at the adult basic, adult secondary, or postsecondary education levels.

Source: U.S. Department of Education, National Center for Education Statistics. (2007). *Digest of education statistics*. Retrieved May 5, 2008, from http://nces.ed.gov/programs/digest/d07/figures/fig_01.asp

A recent reform intended to influence student achievement at all grade levels is the No Child Left Behind Act of 2001 (NCLB). Provisions of the act require that teachers be highly qualified in the subjects they teach. Additionally, NCLB has required states to test students annually to assess whether schools are making adequate yearly progress toward proficiency benchmarks.

Finally, teacher shortages in the United States result from changing demographics in student populations and the availability of teachers qualified in subjects at any given time. This varies by subject and locale. Districts may have enough teachers qualified for a specific subject one year, yet face a shortage the next year. Teacher attrition also can be a factor. While retaining teachers can be a constant challenge, the number of new teachers entering the field generally keeps up with the number of teachers who leave. The subject areas that are most commonly affected by shortages are mathematics, science, special education, and English for non-native speakers. Some strategies adopted by states and districts to address these shortages include financial incentives to both new hires and returning teachers and reforming the teacher induction process.

Language and Population

There is no official language in the United States. The most widely spoken language, with 92 percent of the population, age 5 and over, is English.⁵ English is the language of instruction for academic subjects, including mathematics and science, at all academic levels. The second most common language spoken is Spanish, with 11 percent of the population. The third and fourth most frequently spoken languages are Chinese (Cantonese) and French, which are both spoken by less than 1 percent of the population.

Second-language Instruction

The population of school-age children that speaks a language other than English at home has increased substantially over time. Between 1979 and 2004, the number of school-age children (ages 5–17) who spoke a language other than English at home increased from 3.8 to 9.9 million, or from 9 to 19 percent of all children in this age group. The number of school-age children who spoke English with difficulty also increased, from 1.3 million (or 3% of all school-age children) to 2.8 million (or 5% of all school-age children) over the same time period.⁶ As a result, there has been high demand for teachers of English as a second language. Many states and districts do not have a sufficient number of these teachers. As mentioned previously, financial incentives and other teacher-retention techniques are used in attempts to overcome these shortages.

Emphasis on Mathematics and Science

At present, the federal government is underscoring the importance of mathematics and science education through the No Child Left Behind Act of 2001 (NCLB). All states are required to administer annual assessments in mathematics and reading for grades 3–8 and at least once in grades 10–12. Beginning with the end of the 2007–2008 school year, testing also is required in science at least once during grades 3–5, 6–9, and 10–11. Results from the mathematics assessments are used to determine whether schools are making adequate yearly progress toward the goal of having all students performing at state-set, grade-level proficiency levels by the 2013–2014 school year.⁷ Additionally, the National Assessment of Educational Progress (NAEP), commonly referred to as “The Nation’s Report Card”, assesses states’ progress in several subject areas, including mathematics and science, in grades 4, 8, and 12.

In addition to mandating assessments associated with NCLB and NAEP, Congress passed the America Competes Act, which aims to strengthen mathematics, science, and foreign language education in order to augment the next generation's readiness for a rapidly changing workforce in which technological innovation and global competition are often connected. Within the Department of Education, this initiative has resulted in the formation of a National Mathematics Panel and plans for a Math Now program to advance mathematics education in elementary and middle schools using research-based mathematics instruction techniques.⁸ This act also supports mathematics and science education initiatives in other federal agencies that have science as a part of their mission.

Additionally, there are several smaller federal programs in place to support and supplement mathematics and science education. The Mathematics and Science Partnerships program provides professional development to teachers in subject-specific knowledge. The Upward Bound Math-Science program funds independent programs that encourage students to recognize and develop their potential to excel in mathematics and science and to pursue postsecondary degrees in these subjects.

Overarching Policies Related to Education and the Curriculum for Mathematics and Science

For all states and districts, the curriculum for mathematics and science prescribes a series of topics, content standards, and indicators of student achievement. Most districts publish and/or distribute curriculum frameworks that contain guidance on what should be taught in order for students to be successful. When there are changes to the curriculum framework requirements, many districts hold professional development training meetings to assist administrators and teachers in understanding the changes.

The Mathematics Curriculum in Primary and Lower Secondary Grades

Summary of National Curriculum Guides for Mathematics Through Eighth Grade

The goals, objectives, and processes or methods are prescribed by curriculum. Emphasis is placed on mastering basic skills or procedures, understanding concepts or principles, and applying mathematics in real-life contexts. The curriculum is communicated through publications, online resources, instructional guides, and recommended instructional activities.

Curriculum frameworks vary in individual states. Exhibit 2 shows the mathematics topics and skills generally taught by the end of eighth grade. Additional topics not included in the exhibit may appear in the curriculum in some states. While the exhibit generally represents the material in states' curriculum, the curriculum frameworks always include detailed, grade-level instructional benchmarks, approaches to learning, and instructional resource material.

Exhibit 2 Mathematics Curriculum Topics Taught Through Eighth Grade

Area of Mathematics	Topics Covered by Eighth Grade
Numbers	Whole numbers, place value, factorization, the four operations Computation, estimations/approximations involving whole numbers Fractions, equivalent fractions, ordering of fractions Decimal, place value, ordering, converting to common fractions Representing decimals and fractions using words, numbers, models, number lines Computation with fractions Computation with decimals Representing, comparing, ordering, computing with integers Ratios: equivalence, division of a quantity by a given ratio Conversion to percents, decimals, fractions.
Algebra	Numeric, algebraic, geometric patterns Sums, products, powers of expressions containing variables Evaluating expressions for a given numeric value Simplifying or comparing algebraic expressions Modeling situations using expressions Simple linear equations and simultaneous (two-variable) equations Equivalent representations of functions as ordered pairs, tables, graphs, words, equations.
Geometry	Angles: acute, right, straight, obtuse, reflex Relationships for angles at a point, on a line, vertically opposite angles, those associated with a transversal cutting parallel lines, perpendicularity Properties of geometric shapes: triangles, quadrilaterals, other common polygons Constructing or drawing triangles and rectangles of given dimensions Congruent figures (quadrilaterals, triangles) and their corresponding measures Similar triangles and recall of their properties Relationships between two- and three-dimensional shapes Pythagorean theorem to find length of a side Measurement, drawing, and estimation of the size of angles, length of lines, areas, volumes Measures of irregular or compound areas Cartesian plane: ordered pairs, equations, intercepts, intersections, gradient Line and rotational symmetry for two-dimensional shapes Translation, rotation, reflection.
Data and Chance	Reading data from tables, pictographs, bar graphs, pie charts, line graphs Organizing and displaying data using tables, pictographs, bar graphs, pie charts, line graphs Characteristics of data sets including mean, median, range, shape of distribution Interpreting data sets (draw conclusions, make predictions, estimate values between and beyond given data points) Data display that could lead to misinterpretation Using data from experiments to predict chances of future outcomes Using the chances of a particular outcome to solve problems.

The Science Curriculum in Primary and Lower Secondary Grades

Summary of National Curriculum Guides for Science Through Eighth Grade

The goals, objectives, and processes or methods are prescribed by the curriculum. Emphasis is placed on knowing basic science facts and principles; observing natural phenomena and describing what is seen; and designing, planning, and conducting experiments and investigations (more in eighth than in fourth grade). The curriculum is communicated through publications, online resources, instructional guides, and recommended instructional activities.

The curriculum frameworks of individual states vary. Exhibit 3 shows the science topics and skills generally taught by the completion of eighth grade. Additional topics not included in the table may appear in some states' curriculum. While Exhibit 3 generally represents the material in states' curriculum, specific curriculum frameworks include detailed grade-level instructional benchmarks, approaches to learning, and instructional resource material.

Exhibit 3 Science Curriculum Topics Taught Through Eighth Grade

Area of Science	Topics Covered by Eighth Grade
Biology	Classification of organisms on the basis of a variety of physical and behavioral characteristics Major organ systems in humans and other organisms How the systems function to maintain stable bodily conditions Cell structures and functions Photosynthesis and respiration, as processes of cells and organisms Life cycles of organisms, including humans, plants, birds, insects, etc. Reproduction (sexual and asexual) and heredity (the passing of traits, inherited versus learned characteristics) Role of variation and adaptation in survival/extinction of species in a changing environment Interaction of living organisms in an ecosystem Cycling of materials in nature (water, carbon, oxygen, decomposition) Trends in human population and its effects on the environment Causes of common infectious diseases, methods of transmission, prevention, the body's natural resistance and healing capabilities Preventative medicine methods (diet, hygiene, exercise, lifestyle).
Chemistry	Classification and composition of matter (physical/chemical properties, pure substances and mixtures, separation techniques) Particulate structure of matter (molecules, atoms, protons, neutrons, electrons) Solutions (solvents, solutes, effect of temperature on solubility) Properties and uses of water (composition, melting/boiling points, changes in density/volume) Properties and uses of acids and bases Chemical change (transformation of reactants, evidence of chemical change, conservation of matter) Common oxidation reactions (combustion, rusting) and the need for oxygen and the relative tendency of familiar substances to undergo these reactions.

Exhibit 3 Science Curriculum Topics Taught Through Eighth Grade (Continued)

Area of Science	Topics Covered by Eighth Grade
Physics	Physical states and changes in matter Processes of melting, freezing, evaporation, condensation Energy forms, transformations, heat and temperature, heat transfer Temperature changes related to volume and pressure, changes in movement or speed of particles Basic properties /behavior of light (reflection, refraction, light, color, simple ray diagrams) Properties of sound Electric currents Properties of permanent magnets and electromagnets Forces and motion, use of distance/time graphs Effects of density and pressure.
Earth Science	Earth's structure and physical features The physical state, movement, composition relative distribution of water on Earth Earth's atmosphere and the relative abundance of its main components Earth's water cycle Processes in the rock cycle and the formation of igneous, metamorphic and sedimentary rock Weather data/maps and changes in weather patterns Geological processes occurring over millions of years Formation of fossils and fossil fuels Environmental concerns Earth's resources Relationship of land management to human use Supply and demand of fresh water resources Explanation of phenomena on Earth, based on movement of bodies in the solar system Physical features of the Earth, compared with the moon and other planets.

Instruction for Mathematics and Science in Primary and Lower Secondary Grades

Instructional Time

Since there is no national policy on instructional time, the percentage of instruction devoted to mathematics and science in grades 4 and 8 varies by state, district, and school. In the 2003–2004 school year, the average number of hours per week teachers spent on mathematics in grades 1–4 was 5.4 or 16.5 percent of total instructional time. The average for science in the same grade levels was 2.3 hours per week or 7.1 percent of total instructional time.⁹ In grade 8, instructional time was 3.75 hours per week or 13 percent of total instructional time in each subject (mathematics and science).¹⁰

Instructional Materials, Equipment, and Laboratories

There are no national policies governing the use of instructional materials, equipment, and laboratories. Therefore, individual school districts must manage resources in order to provide schools with the tools they need to teach mathematics and science.

National organizations provide some guidance. The Federal Resources for Educational Excellence publishes an index of teaching and learning resources from federal agencies. These teaching resources are made available through private organizations' and government agencies' websites on all topics in the curriculum for mathematics and science. The National Science Foundation, for example, has a publicly accessible National Science Digital Library to provide exemplary resources for science, technology, engineering, and mathematics.

Purchasing textbooks and curriculum materials is a function of local school districts or individual schools. Some states provide lists of allowable or approved textbooks from which districts or schools may choose. Since textbooks are produced by independent publishing houses with the intention of selling their books to as many districts as possible, many textbooks that are used in U.S. schools have more material and topics of study than a teacher will actually cover in one year.

Grade at Which Specialist Teachers for Mathematics and Science Are Introduced

Under current requirements, all middle and secondary teachers (grades 6–12) are required to be specialists within their fields. However, some states allow teachers with an elementary-level certification to teach at the middle school level. In this case, they may not have specialized knowledge in a discipline even if they are teaching the subject. Teachers are identified as specialists either by passing a state academic subject test or the successful completion of an undergraduate major, holding a graduate degree, completing coursework equivalent to an undergraduate major, or holding advanced certification or credentialing.

Use of Technology

Use of technology in U.S. public schools has been growing in recent years. For example, the ratio of public school students to instructional computers has decreased from 9:1 in 1999 to 8:3 in 2005. The percentage of schools that provide handheld computers to students or teachers for instructional purposes was 19 percent for elementary schools and 17 percent for secondary schools in same year. Additionally, use of information technology has had an impact on instructional planning. The percentage of public schools using the Internet to access data to inform instructional planning was 89 percent in 2005.¹¹

Homework Policies

Homework policies and practices vary across states and local school districts. The amount of time students at a given grade level are expected to spend on mathematics and science homework in a given week varies by the policies established by local school districts, schools, and sometimes teachers. In general, educational activities completed at home are viewed as opportunities for practicing skills and reinforcing understanding of material learned in the classroom. Student assessments are rarely completed outside the classroom, with the exception of long-term, multistep projects.

Teachers and Teacher Education

Education and Training for Fourth and Eighth Grade Mathematics and Science Teachers

Requirements for public school teachers of mathematics and science are the same as those that currently apply to all public school teachers in the United States. All public school teachers must have a bachelor's degree, fulfill their state's requirements for certification (which usually involves a college or university teacher training program), and demonstrate subject knowledge. To demonstrate subject knowledge, new elementary school teachers must pass tests of both teaching skills and the academic areas of basic elementary school curricula, including language arts, reading, and mathematics. New middle and high school teachers must demonstrate expertise in mathematics and/or science either by passing a specified academic subject test or the successful completion of an undergraduate major, a graduate degree, coursework equivalent to an undergraduate major, or an advanced certification or credentialing.

In the 2003–2004 school year, 99 percent of the nation's three million plus elementary and secondary public school teachers had at least a bachelor's degree, and 48 percent also had a master's degree or other degree or certificate beyond a bachelor's degree.¹²

The traditional educational pathway for a public school teacher includes a degree from a 4-year college or university and completion of a teacher training program, including a practicum of supervised teaching experience. In current teacher education programs, early-childhood educators (prekindergarten–grade 3) and elementary school teachers (grades 1–5) usually earn a bachelor's degree in education, while secondary school teachers may earn a bachelor's degree in their specific subject area, a double major in their subject and education, or a master's degree in education in addition to their bachelor's in their subject area. Most colleges and universities, public and private, have a department or school of education that offers teacher-training programs aligned with their state's licensure requirements. In recent years, there has been a proliferation of alternate routes to certification and licensure, primarily in response to a need to find teachers in hard-to-staff schools or in subject areas such as mathematics, science, and special education.

All public school teachers must be licensed. Each state's department of education is responsible for granting licenses, and there are many roads to certification. All states offer different licenses to fit the situation of the teacher seeking certification. Some classifications of licenses include provisional, standard, professional, and permanent. Each license may have a different period of validity. Most states require some testing, such as tests of basic skills (reading, writing, and mathematics); tests to show mastery of the subject to be taught; and/or tests in general pedagogy. Licensure processes and requirements are currently under review in many states in order to meet the requirements of the No Child Left Behind Act of 2001.

As a result of this act, all teachers must now be highly qualified, as defined by law. This means that all teachers must obtain a teaching license from their state, have at least a bachelor's degree, and demonstrate expertise in their field. For tenured and experienced teachers, demonstrating expertise may involve only a careful review of a teacher's

professional record. For newer teachers, demonstrating expertise requires passing state tests and/or holding a degree or major in the subject area to be taught.

Some states require that all teachers obtain a master's degree in education within a certain period of time after they start teaching. Failure to obtain a master's degree within a certain time period may result in a freeze of scheduled pay-step increases after a certain number of years or may disqualify a teacher from holding a professional license.

Most states require continuing professional development and education for renewal of teacher licenses. Often school districts will provide opportunities for teachers to continue their education through professional development activities organized by the school district. Many districts have professional development coordinators or specialists whose primary focus is to assist teachers with professional development and attaining credits toward relicensure.

Teacher Professional Development in Mathematics, Science, and Technology

There are no national policies that prescribe the content and methods of professional development programs. Some approaches to professional development implemented by states are short-term workshops, summer institutes for teachers to receive specialized training and equipment, master teacher programs that provide specialized training and financial incentives to participating teachers, professional development opportunities for teachers specifically in high-needs districts that may include a combination of the above, and special training and support for teachers of advanced secondary school courses. Most teachers' professional development activities are supported or organized by their schools or school district. A 2006 study reported that 92.5 percent of teachers received some sort of professional development support from their district or school, such as scheduled professional development time in the school year, release time from teaching, reimbursement for a conference or workshop, a stipend for activities outside regular work hours, or other various supports for professional development activities.¹³

Examinations and Assessments

National or Regional Examinations

All states require standardized tests to be administered to students from elementary, middle, and high school. Under the No Child Left Behind Act of 2001, all states and schools must show that they are making adequate yearly progress towards the goal of all students meeting state-set proficiency levels. However, states may choose their own assessments, and few states give the same test. The stakes are high for schools. Those that do not show adequate yearly progress through standardized tests face interventions. For students, however, there are rarely high-stakes tests in elementary and middle school.

The National Assessment of Educational Progress (NAEP) is the only nationally representative and continuing assessment of what U.S. students know and can do in various subject areas. NAEP has been collecting nationally representative data since 1969 and state representative data since the early 1990s. Since 1969, assessments have been conducted periodically in reading, mathematics, science, writing, U.S. history, civics,

geography, and the arts. While the sample for this national assessment is large and represents states, the assessment is not designed to yield results for individual students or schools, thus no stakes are attached to the results.

Other Tests

Other standardized testing that takes place throughout the United States includes the Scholastic Assessment Test and American College Testing Assessment, both of which are commercial tests developed and administered by private organizations, taken primarily by upper high school students, and used in the college or university admission process. Admission to institutions of postsecondary education is not solely dependent on test scores, rather, most schools' admissions offices look at a number of factors, including a student's class rank, grade point average, and extracurricular activities. Some postsecondary institutions, including most 2-year community colleges, do not require these test scores for admission.

Monitoring Individual Student Progress

In public schools, grade reports are issued each quarter or approximately every 9 weeks. Semester grades and yearly grades also are given in many districts. Usually, only one final grade may appear on a middle school or high school transcript, representing the student's performance in a course for the entire school year. High school transcripts that show courses taken and grades earned are used to establish whether students have met the state's graduation requirements. Transcripts also are used in college entrance applications as a record of academic performance. In elementary and middle school, parents may meet with teachers between quarter grade reports to discuss students' progress.

In elementary and middle schools, the monitoring of individual students' long-term progress is generally the responsibility of teachers and parents, except in cases in which students are identified as having special needs. In this case, the school district and school are responsible for monitoring student progress toward educational goals. However, in high schools, students are provided guidance counselors to assist them in monitoring their own progress in school and toward postsecondary goals.

Grade Promotion and Retention Policies

The U.S. Department of Education and individual state departments of education do not have one formal policy for determining grade retention and promotion. Usually, a school will base a student's promotion to the next grade on a combination of the following: passing grades in a certain number of courses (including core academic courses), performance on standardized tests, performance on final exams (in middle and high school), or successful completion of summer school courses (if academic courses were not passed during the school year). Grade retention is on the decline in the United States. The percentage of students who were retained at some point in their public education dropped from 16 percent in 1995 to 10 percent in 2004.¹⁴

Suggested Readings

Department of Education website: <http://www.ed.gov/index.html>

Education Commission of the States, ECS State Notes and Online Databases: <http://www.ecs.org>

ED Priorities and Initiatives: <http://www.ed.gov/about/inits/ed/index.html?src=ln>

Innovations in Education book series: <http://www.ed.gov/about/pubs/intro/innovations.html>

National Center for Education Statistics: <http://nces.ed.gov>

Research and Statistics: <http://www.ed.gov/rschstat/landing.jhtml?src=rt>

U.S. Network for Education Information: <http://www.ed.gov/about/offices/list/ous/international/usnei/edlite-index.html>

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- 12 Strizek, G., Pittsonberger, J., Riordan, K., Lyter, D., & Orlofsky, G. (2007). *Characteristics of schools, districts, teachers, principals, and school libraries in the United States: 2003–04 schools and staffing survey*. (NCES 2006-313 Revised). Table 20. U.S. Department of Education, National Center for Education Statistics. Washington, DC: U.S. Government Printing Office.
- 13 Choy, S.P., Chen, X., & Bugarin, R. (2006). *Teacher professional development in 1999–2000* (NCES 2006-305). Table 12. U.S. Department of Education, National Center for Education Statistics. Washington, DC: U.S. Government Printing Office.

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Yemen

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Introduction

Overview of Education System

The general education system in Yemen has three stages: preschool, basic education, and 3-year secondary school. Basic education comprises the first 9 years of schooling. Previously, basic education was divided into 6-year primary and 3-year middle schools. Constitutionally, education is free in all stages and is mandatory for the 9 years of basic education.^{1,2} By law, every person has the right to an education. The Ministry of Education is responsible for allocating national resources to operate the public education system and determining the curricular and pedagogical standards.

The curricular guidelines, offered by the ministry, provide a conceptual orientation, while the achievement standards are aimed at directing the focus of the curriculum for the cycles of grades, 1–6, 7–9, and 10–12. A national curriculum is prescribed for all children in the 12 grades of general education.

Most schools are public institutions, however, by law, the private sector has the right to establish schools and institutes to provide education.³ Presently, only 3 percent of general education schools are private.⁴

Schools in Yemen are mostly in rural areas since 74 percent of the total population live in rural areas.⁵

Language and Population

Under the Constitution of the Republic of Yemen, Yemen's official language is the Arabic language.⁶ Therefore, education is primarily offered in the Arabic language. However, some private Yemeni schools teach in English.

Emphasis on Mathematics and Science

There is no explicit policy emphasizing mathematics or science instruction. However, since 2000, the curriculum of each subject has undergone major changes. Starting in 2008, the ministry's annual plan is focused mostly on reform of the curriculum in all

subjects including mathematics and science. The underlying theme of this reform is competency-based education.

The Mathematics Curriculum in Primary and Lower Secondary Grades

Summary of National Curriculum Guides for Mathematics Through Eighth Grade

Instruction in grades 1–6 emphasizes the use of mathematics for formulating and solving concrete problems and applying judgment about the soundness of the solutions proposed. It also focuses on describing the relationship between everyday language and the language of mathematics symbols, so that the student may distinguish between different forms of mathematical representation, such as word problems, tables, diagrams, and graphs. According to curricular guidelines, students in the **grades 1–6** cycle should achieve the following.

- *Algebra and numbers*: recognize the meaning of numbers in the context of measurement, counting, comparison, and location; recognize regularities and patterns; and solve word problems in additive situations.
- *Geometry and measurement*: describe and produce figures and explore the results from their combination and subdivision; use geometrical diagrams to identify objects in everyday contexts and associate such diagrams with measurement; and master concepts of perpendicularity and parallelism.
- *Data and statistics*: summarize, classify, and organize data and present this information in pictograms, tables, and diagrams.

The curricular guidelines in **grades 7–9** emphasize the identification, description, and representation of concepts and relationships in different situations, as well as their application in solving problems in mathematical and nonmathematical contexts. The expectations for students in these grades are as follows.

- *Algebra and numbers*: formulate and solve problems of direct proportionality in the context of multiplication; interpret the meaning of fractions in different contexts involving measurements, differences, and quotients and compare different forms of expression; interpret various situations through simple arithmetic equations and inequalities, present them graphically, and use number systems extensively; understand and apply the properties of operations in different number systems to problem solve; understand and apply the theory of numbers; and describe and present various situations in arithmetic and geometric contexts and formulate and solve word problems in additive situations of transformations.
- *Geometry*: formulate and solve problems involving scale factors and problems requiring estimation techniques; recognize the effects of different transformations; present and solve problems by applying the basic concepts of proportionality and the geometric properties of congruence, similarity, and symmetry; compare and classify two- and three-dimensional objects according

to their properties; visualize the possible results of applying transformations on a plane into two-dimensional objects and begin to understand the concept of congruence; differentiate measurable properties of objects; and use different procedures and strategies for calculating areas and volumes.

- *Data and statistics*: present and interpret data in tables, graphs, and diagrams, using information from local sources and simple experiments.

The Science Curriculum in Primary and Lower Secondary Grades

Summary of National Curriculum Guides for Science Through Eighth Grade

The ministry's curricular guidelines for **grades 1–4** emphasize observation, classification, inquiry, communication, measurements, approximation, and use of time-space relations. The curricular guidelines in **grades 5–9** emphasize the transition from the concrete to the abstract, according to the development of student's knowledge and scientific understanding. The science curriculum is composed of the following domains.

- Living and nonliving things
- Human health
- Power and energy
- Atmosphere and weather
- Matter and characteristics
- Solar system
- Science and technology

Instruction for Mathematics and Science in Primary and Lower Secondary Grades

Instructional Time

For mathematics, the study time for grades 1–3 is five periods weekly, with each period averaging 42.5 minutes. For grades 4–9, the number increases to six periods per week. The week is 6 half-days. A half-day averages 5.5 periods.

For science, there are two study periods weekly for grades 1–3, three periods for grades 4–6, and four periods for grades 7–9.

Instructional Materials, Equipment, and Laboratories

The textbook is the chief instructional material. Some charts and similar material are supplied by the ministry. Laboratories are mostly in secondary schools.

Grade at Which Specialist Teachers for Mathematics and Science Are Introduced

Teachers in grades 1–6 mostly have general qualifications, but from grades 7–12, the teachers must be specialized in specific subject areas.

Use of Technology

The Ministry of Education embarked on a project, Integration of Information and Communication Technology in Education, which was launched in 2008 and targets the following areas.

- Provision of computer technologies and Internet connectivity for schools through agreements with the Ministry of Communications and the private sector
- Relevant professional development of teachers and administrators
- Development of strategies for technology integration into the curriculum.

Teachers and Teacher Education*Education and Training for Fourth and Eighth Grade Mathematics and Science Teachers*

Previously, teacher education for grades 1–6 required completion of the following programs in historical order: a 3-year postprimary school diploma, a 3-year postmiddle school diploma, a 5-year postprimary school diploma, and a 2-year postsecondary school diploma. Now, every potential teacher must have a bachelor's degree no matter which grades he or she will teach. Currently, this applies only to practicing teachers in grades 7–12.

Teacher Professional Development in Mathematics, Science, and Technology

Several teacher professional development programs are underway and will continue until all lower grade teachers (who usually have junior and senior secondary school certificates or equivalent Teacher Training Institute diplomas) are trained. At the higher education level, teacher professional development programs also have been under review. The MASTERY project (Mathematics and Science Teacher Education Reform in Yemen), which was established in 2005 in cooperation with the Netherlands, is an example of one of these programs. Its newly developed programs that prepare teachers of mathematics, biology, physics, and chemistry have been introduced in four universities starting in the 2007–2008 academic year. The project's strategy to develop the aforementioned programs included training workshops, coaching, exposure to good practice in the region and in the Netherlands, and equipping teacher education laboratories.

Examinations and Assessments*National or Regional Examinations*

In accordance with the government's strategic policies, students sit for two national examinations: a general examination for entering higher education at the end of secondary education (grade 12) and nationally managed regional examinations at the end of basic education (grade 9) in all curriculum subjects.

Yemen is in the process of establishing a National Center of Measurement and Evaluation in order to reform its programs of testing and monitoring the quality of education.

Monitoring Individual Student Progress

Assessments in grades 1–8 and 10–11 are designed by each school. It is mandatory that students be quizzed monthly, monitored through homework, and examined at midyear and at the end of the year. The grade for the year is aggregated from the 40 percent allocated to monthly quizzes and homework assessments (20% for first term and 20% for the second term), 30 percent to a midyear examination, and 30 percent to the end-of-year examination.

Grade Promotion and Retention Policies

In grades 1–3, a child is automatically promoted. Students in grades 4–8 have to score 50 percent correctly on the summative assessment in order to be promoted, otherwise, the student needs to repeat the grade until achieving the passing score.

The same passing criterion of 50 percent and policy on repeating a grade applies to students in grades 9 and 12 who are assessed nationally and regionally, as mentioned above.

Suggested Readings

www.masteryproject.net
www.moe.gov.ye
www.mtevt.org/site_en/index.asp
www.sfd-yemen.org
www.yemen-nic.net/English%20site/index.htm

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Benchmarking Participants



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Introduction

Overview of Education System

Alberta, like other provinces in Canada, is responsible for developing its own curriculum and has the authority to develop provincial assessments. All schools must follow the mandated curriculum, and teachers are responsible for developing instructional plans that assist students in achieving the learning outcomes outlined in the programs of study. School is mandatory for children, ages 6 to 16.¹

There is no single textbook used throughout the province, and teachers select, from an approved list of textbooks, which ones best fit their needs. Alberta Education designs curriculum in consultation with teachers and other stakeholders involved in education. After detailed development and pilot implementation, Alberta Education officially releases new curricula. Each teacher is responsible for implementing new, relevant curriculum as it is introduced.

In Alberta, schools are generally grouped into three levels: elementary (grades 1–6), junior high (grades 7–9), and senior high school (grades 10–12). There are four main types of schools operating within Alberta: public, separate (Catholic), private, and charter. A charter school is one that must be approved by the Minister of Education and is established to provide innovative, different, or enhanced programming to improve student learning. Students also have the right to a home education.

Early childhood programs serve children before grade 1 and include kindergarten. Attendance in these types of programs, such as kindergarten, is voluntary and may be offered by public or private schools or other private institutions. Students attending kindergarten should have access to at least 475 hours of instruction per year.

Language and Population

In Alberta, the official languages of instruction are English and French, with the majority of students receiving English instruction. Several bilingual and immersion programs also are offered in languages such as Arabic, Chinese, German, Ukrainian, and Spanish.

Second-language Instruction

With the population of students who speak English as a second language continuing to grow by an average of 14 percent each year, the needs of these students continue to be met. The *English as a Second Language Elementary Guide to Implementation* provides teachers with strategies for teaching these students.² Many of the accommodations and effective strategies for teaching students who speak English as a second language are similar to those used with students who have special needs.

The Mathematics Curriculum in Primary and Lower Secondary Grades

Summary of Curriculum Guides for Mathematics Through Eighth Grade

The Department of Education organizes their guidelines into the following areas: communication, connections, estimation and mental mathematics, problem solving, reasoning, technology, and visualization.³

Communication refers to the fact that students need to communicate mathematical ideas clearly and effectively, orally, and in writing.

Connections implies that students need numerous and varied experiences in order to appreciate the usefulness of mathematics and, at the same time, to explore connections within mathematics, from mathematics to other disciplines, and from mathematics to their daily experiences.

Estimation and mental mathematics involves learning when and how to estimate. The context of a problem helps to determine when it is necessary or desirable to have an exact answer or an estimate of that answer.

Problem solving is the focus of mathematics at all grade levels. The development of each student's ability to solve problems is essential. Students develop a true understanding of mathematical concepts and procedures when they solve problems in meaningful contexts.

Reasoning refers to the fact that students need to develop confidence in their ability to reason and to justify their thinking within and outside of mathematics. The power of reasoning helps students make sense of mathematics, be logical in their thinking, and convince others.

Technology entails students saving time by using calculators or computers to perform complex calculations that will help them better understand mathematical concepts. Students then can understand the relationships among concepts and use these relationships to solve problems.

Visualization involves thinking in pictures and images. This is the ability to perceive, transform, and recreate different aspects of the visual-spatial world. The use of images in the study of mathematics provides students with the opportunity to understand mathematical concepts and to make connections among them.

Within this structure, strands for the grades are established. Strands are the formal aspects of the discipline of mathematics that form the foundation of this program of study and act as connections across the grades. The four strands described below apply to the entire kindergarten to grade 12 mathematics framework, which reinforces the inter-

relationship of mathematical concepts and skills. Each strand also is split into substrands. The four strands are number, patterns and relations, shape and space, and statistics and probability.

Number consists of two substrands: number concepts and number operations. In number concepts, students use numbers to describe quantities and represent numbers in multiple ways. In number operations, students demonstrate proficiency with calculations, and to decide which arithmetic operation or operations can be used to solve a problem and then solve the problem.

Patterns and relations contains two substrands: patterns and variables and equations. Students use patterns to describe the world and solve problems. Variables and equations involve students representing algebraic expressions in multiple ways.

Shape and space consists of three substrands: measurement, 3-D objects and 2-D shapes, and transformations. In measurement, students describe and compare everyday phenomena using either direct or indirect measurement. Students describe the characteristics of 3-D objects and 2-D shapes and analyze the relationships among them. In transformations, students perform, analyze, and create transformations.

Statistics and probability contains two substrands: data analysis and chance and uncertainty. Within data analysis, students collect, display, and analyze data to make predictions about a population. In chance and uncertainty, students use experimental or theoretical probability to represent and solve problems involving uncertainty.

The Science Curriculum in Primary and Lower Secondary Grades

Summary of Curriculum Guides for Science Through Eighth Grade

The Department of Education's beliefs about science education are explained below.

The elementary science program (grades 1–6) engages students in a process of inquiry and problem solving in which they develop both knowledge and skills. The purpose of the program is to encourage and stimulate children's learning by nurturing their sense of wonderment, developing their skills and confidence in investigating their surroundings and helping them build a foundation of experience and understanding upon which later learning can be based.⁴

The secondary science program (grades 7–9) is guided by the vision that all students have the opportunity to develop scientific literacy. The goal of scientific literacy is to develop the science-related knowledge, skills, and attitudes that students need to solve problems and make decisions, and, at the same time, help them become lifelong learners, maintaining their sense of wonder about the world around them.⁵

The Alberta science program addresses its goals by making sure that science education does the following.

- Encourage students at all grade levels to develop a critical sense of wonder and curiosity about scientific and technological endeavors
- Enable students to use science and technology to acquire new knowledge and solve problems so they may improve the quality of their own lives and the lives of others

- Prepare students to critically address science-related societal, economic, ethical, and environmental issues
- Provide students with a foundation in science that creates opportunities for them to pursue progressively higher levels of study, and prepares them for science-related hobbies appropriate to their interests and abilities
- Enable students, of varying aptitudes and interests, to develop knowledge of the wide spectrum of careers related to science, technology, and the environment.

The standards and program emphasis for the elementary level (grades 1–6) are briefly described below.⁶ Each area within the elementary science program provides a rich source of topics for developing questions, problems, and issues that provide starting points for inquiry and problem solving. By engaging in the search for answers, solutions, and decisions, students have a purpose for learning and an opportunity to develop concepts and skills within a meaningful context.

Learner expectations for the elementary science program are linked to two main areas of skill emphasis: science inquiry and problem solving through technology. The skills developed in these two areas are related, but have a somewhat different focus. In science inquiry, the focus is on asking questions and finding answers based on evidence. The outcome of inquiry is knowledge. In problem solving through technology, the focus is on practical tasks, or finding ways of making and doing things to meet a given need, using available materials. The outcome of problem solving is a product or process that a person can use.

The standards for the program at the secondary level (grades 7–9) are described in terms of emphasis on science, technology, and society; knowledge; skills; and attitudes.⁷ In the science, technology, and society skill emphasis, students develop an understanding of the nature of science and technology, the relationship between science and technology, and the social and environmental contexts of science and technology. Students construct knowledge and understanding of concepts in life science, physical science, and earth and space science, and apply this understanding to interpret, integrate, and extend their knowledge. They also learn to develop the skills required for scientific and technological inquiry, solving problems, communicating scientific ideas and results, working collaboratively, and making informed decisions. Additionally, students are encouraged to develop attitudes that support the responsible acquisition and application of scientific and technological knowledge to the mutual benefit of self, society, and the environment.

Instruction for Mathematics and Science in Primary and Lower Secondary Grades

Instructional Time

Mathematics is introduced in grade 1 and by grade 4, it makes up 15 percent of classroom instructional time. Likewise, science is introduced in grade 1 and at grade 4, it makes up 15 percent of classroom instructional time. At the secondary level (grades 7–9), instructional time is specified in hours instead of percentages. For both mathematics

and science, the required instructional time is a minimum of 100 hours per year for each subject.⁸

Instructional Materials, Equipment, and Laboratories

The ministry compiles a list of authorized, basic resources that support teaching the curricular outcomes. These resources are subjected to an in-depth review and content validation and must meet the Guidelines for Recognizing Diversity and Promoting Respect.

Resources for teaching mathematics and science are divided into basic student learning resources, student support resources, and teaching resources. Basic resources address most of the course outcomes, while support resources assist in meeting some of the outcomes. Resources are available in various forms such as print, audio, video, manipulatives, or computer software.⁹

Use of Technology

Alberta has a program of study for information communications technology, which provides technology-specific outcomes for students that can be integrated into many subject areas including mathematics and science. Students are encouraged to use technology to facilitate their work. Authorized CD-ROM resources also are available to support mathematics and science instruction.

In mathematics, both computers and calculators can be used to perform complex calculations and help students better understand mathematical concepts. In some cases, technology allows teachers to ask questions requiring a high level of thinking and will allow students to solve complex, multifaceted problems. Computers and calculators also can decrease the time spent on computations when other mathematical learning is the focus, as well as reinforce the learning of basic facts. Technology can foster environments in which the growing curiosity of students can lead to rich, mathematical discoveries. In these environments, students can control the exploration of mathematical ideas.¹⁰

Teachers and Teacher Education

Education and Training for Fourth and Eighth Grade Mathematics and Science Teachers

Elementary and secondary school teachers must complete at least 4 years of postsecondary education to receive a Bachelor of Education degree. A supervised practicum in the field is mandatory in any teacher education program. Although there are no requirements specific to teaching mathematics and science, each university requires that a specific number of mathematics or science courses be taken in order for a degree to be granted in that specific area of focus. Curriculum courses are offered to teacher education students, with several instructional courses taken by those specializing in mathematics and science. After receiving a degree, a teacher is granted a probationary teaching certificate from Alberta Education. After 2 years and upon recommendation from their school district, a teacher may be granted a permanent teaching certificate.

Teacher Professional Development in Mathematics, Science, and Technology

Teacher professional development workshops are handled by each school district and by the regional consortia that coordinates professional development opportunities. Additionally, teacher conventions are held each year that provide opportunities for teachers to become acquainted with the newest research and news with regard to their areas of instruction.

Examinations and Assessments

In addition to extensively used classroom assessments, provincial achievement tests are administered in English language arts (grades 3, 6, and 9), mathematics (grades 3, 6, and 9), social studies (grades 6 and 9), and science (grades 6 and 9). A teacher has the option of using the marks from these tests as part of the final class grade, but it is not mandatory.

In grade 12, students must take diploma examinations in order to receive their high school diploma. Diploma examinations are administered in mathematics, English language arts, biology, chemistry, physics, science, social studies, and French language arts courses. Each examination is combined with the student's school-awarded mark and is worth 50 percent of a student's final grade in a course.

Following each test administration, detailed reports at the district, school, and class levels, based on the data collected from the provincial assessment, are generated and sent back to schools and teachers to help them identify students' strengths and areas for improvement in learning.^{11,12}

Other Tests

In addition to a variety of informal mathematics and science inventories, teachers use an assortment of standardized tests to assess mathematics and science achievement. Commonly used tests include the Brigance Comprehensive Inventory of Basic Skills-Revised; the Canadian Achievement Test; the Canadian Test of Basic Skills; the Wechsler Individual Achievement Test, Canadian Version; and the Woodcock Johnson III Tests of Achievement.

Monitoring Individual Student Progress

Classroom teachers use a variety of assessment approaches including ongoing classroom assessment and provincial assessments to monitor student progress. Teachers communicate student progress through report cards and parent-teacher conferences, as well as informally through regular communication with parents.

Grade Promotion and Retention Policies

In Alberta, the decision to promote a student to the next grade in elementary or junior high or retain them in their current grade is left to the local school jurisdictions. In high school, if a student does not pass a particular high school subject, then they are allowed to retake the course until they pass it with a minimum mark of 50.

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Basque Country, Spain

Basque Institute for Research and Evaluation in Education (ISEI-IVEI')

Introduction

Overview of Education System

In the Basque Country, responsibility for ultimate educational decision-making rests with the Basque government's Minister of Education, Universities, and Research.² There are also four vice ministries with responsibilities for administration and services, education, vocational training, ongoing learning, and universities and research. For example, decisions about the curricula for mathematics and science are made by the head of the Educational Innovation Department, which is under the Vice Ministry of Education.

Basque Country has its own curricula, produced by groups of experts in the different areas, published by the Basque government's Department of Education, Universities, and Research, and available to the educational community via different media, including its website.

Preprimary education is not obligatory, but 100 percent of students attend preschool by the age of 3. Public centers offer education for children between the ages of 3 and 6, and an increasing number of centers also offer education from ages 0 to 2.

Compulsory education is completed in 10 years, for students ages 6 to 16, and is divided in two stages, primary (ages 6 to 12) and compulsory secondary (ages 12 to 16). Baccalaureate and vocational training are not compulsory but are offered in state schools.

The Basque education system has two networks. The public network is managed by the Basque Country's Education Department and the private network, which receives state subsidies, is managed by private institutions, religious institutions, or cooperatives of families.

There are three models of education (see Exhibit 1) according to the language of instruction: A, B, and D. In model A, all subjects are taught in Spanish, and 3 hours per week they are taught in the Basque language. In model B, half the subjects are taught in Basque and half in Spanish, including literacy and mathematics. However, this division by subjects may vary according to school decisions. Model D serves to maintain the

language of students whose first language is Basque and provides immersion for those whose first language is not Basque.

Exhibit 1 The Educational Cycles and Linguistic Models in the Basque Country's Education System

Age	Stage and Linguistic Models		Comments
0–2	1st Cycle	Infant education (6 levels) Model A, B, or D	Schooling is not compulsory at this stage.
3–6	2nd Cycle		All schools in the Basque Country have the 2nd Cycle (three levels). Many schools have 2-year-old groups, and the tendency is increasing.
6–8	1st Cycle	Primary education (6 levels) Model A, B, or D	This is a compulsory stage.
8–10	2nd Cycle		
10–12	3rd Cycle		
12–14	1st Cycle	Compulsory secondary education (4 levels) Model A, B, or D	This is a compulsory stage.
14–16	2nd Cycle		The overriding philosophy is a comprehensive school. Before the reform, students at 14 used to split into a 4-year baccalaureate or vocational training.
16–18	Baccalaureate (upper secondary) or Vocational studies (2 levels) Model A or D		This stage is not compulsory. This is only for students who have achieved the curricular objectives in the previous stage. Students who have not finished compulsory secondary can take vocational studies or training cycles (leading to level 2 qualifications in the labor system standards of the European Union). Baccalaureate qualifications are needed both for university and upper vocational studies (polytechnic equivalent).

Language and Population

The Basques occupy a Spanish autonomous community known as the Basque Country (*Euskadi*), which has significant cultural and political autonomy. This includes the northern Basque Country in the French department of the *Pyrennées Atlantiques* and the autonomous community of Navarre in Spain, which together make up the historical Basque Country (*Euskal Herria*).

Basque (*Euskara*) is the language spoken by the Basque people who inhabit the Pyrenees in north central Spain and the adjoining region of southwestern France. It is spoken by approximately a quarter of the Basques, with its stronghold in the contiguous area formed by eastern Guipuzcoa, northwestern Navarre, and the sparsely populated French Lower Navarre and Soule. Basque is not spoken in most of Alava, western Biscay, or the southern half of Navarre. Out of a total of nearly 3,000,000 Basques, it is estimated that some 632,000 are Basque language speakers, of which approximately 566,000 live in the Spanish Basque country, with the rest residing in the French part.

Today, Basque is a lesser-used language in the Basque territories, but the Basque education system can be a powerful tool to spread the knowledge of the language. More than 90 percent of students (infant education) are enrolled in Basque immersion programs.

All students speak Spanish, even the adults. Almost all Basque speakers are bilingual, but this is not the case for Spanish speakers.

Second-language Instruction

In the linguistic models described above, model A is instruction in Spanish (Basque and literature are the only subjects in Basque); B is middle immersion (50% Basque and 50% Spanish, in theory); and model D is total immersion (Spanish and literature are the only subjects in Spanish). Foreign language, mainly English, is taught, beginning with 4-year-old students, but not very intensively.

Mathematics and science are mainly taught in Basque or Spanish depending on the linguistic model chosen by the student, but they are also taught in English because the number of trilingual schools, in which some subjects are being taught in English, is increasing. Therefore, the language of instruction varies.

This is an important issue in deciding the language of the test. At grade 8, students do not master Basque, English, or Spanish as if they were native speakers, but they are able to perform properly in mathematics or science if they answer the test in their mother tongue.

The Mathematics Curriculum in Primary and Lower Secondary Grades

Summary of National Curriculum Guides for Mathematics Through Eighth Grade

The mathematics curriculum for the **third and fourth grades of primary education** consists of the following.

Numbers and operations

- *Natural numbers and fractions*: learn numeracy, the decimal number system, fractions to express division, and ratios in real contexts; comparisons between simple fractions and between natural numbers and simple fractions by ordering and their representation on the number line; the meaning of multiplication and division and their usefulness in daily life; and how to use division in real contexts and understand it as the inverse of multiplication.
- *Calculation strategies*: learn automatic mental arithmetic and construction and memorization of multiplication tables; calculate addition, subtraction, two-digit multiplication, and one-digit division using academic algorithms; and use varied instructional materials and a calculator.

Measurement: estimation and the calculation of magnitudes

- *Length, weight/mass, and capacity*: begin to learn the decimal metric system, comparisons and ordering of units and amounts of the same magnitude, and the production and use of personal measurement strategies.

- *Measuring time*: learn units of time measurement and how to read the time on analog and digital clocks.
- *Monetary system*: recognize and use legal tender (coins and notes) and establish equivalences.

Geometry

- *Situation in space, distances, angles, and turns*: learn an elementary representation of known spaces, plans, and models; read and interpret maps and simple plans; describe positions and movements in a topographical context; and learn coordinate axes.
- *Flat and spatial figures*: identify, describe, and construct flat and spatial figures in daily life; learn about the classification of polygons, sides, and vertices and circumference and circles; learn about geometric bodies, such as cubes, spheres, prisms, pyramids, and cylinders, as well as edges and faces; compare and classify angles.
- *Regularities and symmetries*

Treatment of information, randomness, and probability

- *Graphs and tables*: understand data tables, data collection, and recording; produce data tables for objects, phenomena, and family situations; and produce simple graphs with data on objects, phenomena, and familiar situations.
- *The random nature of some experiences*: begin to understand the language of randomness and the use of an initial language appropriate for describing situations and experiences of randomness in familiar situations.

Problem solving

- Identify and solve problems in daily life in which one or several of the four operations intervene and learn about open-ended problem solving.

The objectives for teaching mathematics at the **lower secondary stage** include the following competencies.

- Consider and solve, individually or as a group, problems taken from daily life and from other science subjects or mathematics, choosing and using different strategies, reasoning through the solution process, interpreting the results, and applying them to new situations in order to act more efficiently in the social environment.
- Identify, relate, describe, and represent mathematical elements (numbers, statistical data, graphs, plans, calculations, figures, randomness, etc.) in the social world (news, opinions, advertising, etc.) and the scientific world, critically analyzing the functions they perform in order to understand and make better use of the messages and information received.
- Use the characteristic tools of mathematical language and expression (numbers, tables, graphs, figures, usual nomenclatures, etc.) independently and creatively

to explain individual thought clearly and coherently, using the most appropriate technological resources.

- Represent and describe different objects, mathematical situations, compositions, and spatial configurations based on information given or from the surrounding environment, applying the necessary geometric knowledge to understand and analyze and solve problems in the physical world.
- Confidently perform estimates and calculations (numerical, metric, algebraic, etc.) using the most suitable procedures for each situation (mental arithmetic, written calculation, calculator, computer, etc) to interpret and evaluate different situations in daily life, deciding in each case the advantages of each procedure and subjecting the results to systematic review.
- Reason and argue, producing solid arguments and justifications to rationalize and present results and conclusions, criticize and refute other arguments, and apply them to new situations.
- Learn the appropriate use of different technological and communication resources (calculators, computers, etc.) for calculations and for searching, treatment, and representation of different types of information, and also, to help in learning mathematics.
- Integrate mathematical knowledge and procedures (the systematic exploration of alternatives, precision in language, flexibility, and perseverance) in the sets of knowledge that are being acquired in different areas so that they can be used to solve problems creatively, analytically, and critically.
- Evaluate mathematics as an integral part of our culture from both the historical point of view and from the perspective of its role in modern society and apply the acquired mathematical competencies to analyze and evaluate social phenomena, such as cultural diversity, respect for the environment, health, consumption, gender equality, and peaceful coexistence.
- Demonstrate a positive attitude to problem solving and show confidence in their own capacity to tackle problems successfully; acquire an appropriate level of self-esteem; and enjoy the creative, manipulative, aesthetic, and utilitarian aspects of mathematics.

A summary of the mathematics curriculum in the **second year of compulsory secondary education** includes the following.

- *Problem solving*: learn general problem-solving methods (based on the work of Polya and Miguel de Guzmán); learn the most common heuristics for problem solving, including trial and error, solving a simpler problem, dividing the problem into small problems, reformulating a problem, the use of tables, exhaustive recount, change of state, and diagrams or drawings; use calculators and computers (spreadsheet and mathematics assistants); and use calculators to develop mental arithmetic strategies.

- *Numbers and algebra*: learn about whole numbers, including operations with whole numbers, the hierarchy of operations, and rules for using brackets in simple calculations; the powers of whole numbers with natural exponents, including operations with powers and scientific notation to represent large numbers; square roots; relationships between fractions, decimals, and percentages; direct and inverse proportionality, including proportional reasoning; algebraic language, including obtaining formulas and general terms based on observing rules and regularities; and first degree equation and its application to problem solving.
- *Geometry and measurement*: learn plane figures, such as triangles, quadrilaterals, and other polygons; their elements and characteristics; and Pythagoras' theorem; similarity of figures, including proportionality between segments and ratio of areas of similar figures; Thales' theorem, including similarity of triangles, scale representation, and maps; plane symmetries; polyhedras and the most common bodies of revolution, including the cube, prism, pyramid, cylinder, cone, and sphere, as well as plane developments and characteristic elements, and classification; and estimation and calculation of perimeters, areas, and volumes of figures and bodies using various procedures.
- *Functions and graphs*: learn relations between magnitudes and functional dependency; different forms of expressing a function, including verbal, tabular, graphic, and algebraic description; general characteristics of graphs; direct and inversely proportional magnitudes; and the proportionality constant.
- *Statistics and probability*: learn basic elements of descriptive statistics; statistics tables; absolute, relative, and accumulated frequencies; statistical graphs; centralization measures, including the mean, median, and mode; random phenomena and random events, including event frequency and relative frequency; and probability theory, including Laplace's rule.

The Science Curriculum in Primary and Lower Secondary Grades

Summary of National Curriculum Guides for Science Through Eighth Grade

The content of primary education in science has been grouped into blocks that identify the main fields in the area. They are not given in any order in terms of hierarchy or content and therefore, do not constitute a proposal on how to organize the teaching of the subject. However, as one of the main objectives in this stage is to form an individuals' ability to interact with their environment and have critical awareness to gradually master increasingly wider spatial spheres, the different blocks for **primary education** in science begin with an attitudinal content.

- *Block 1*: the environment and conservation, including content that ranges from spatial perception and representation to the universe, the climate and its influence, water and its exploitation, and people's capacity to act on nature and its repercussions.
- *Block 2*: the diversity of living beings, directed towards knowledge, respect, and the appreciation of living beings.

- *Block 3:* health and personal development, integrating knowledge, abilities, and skills so that knowledge of one's own body can help prevent risk behaviors and encourage initiatives to develop and strengthen responsible behaviors and healthy life styles.
- *Block 4:* persons, cultures, and social organizations, including content oriented toward understanding how society works based on both the analysis of familiar organizations and knowledge of institutions in the Basque Country and the other Basque culture communities included within the Basque homeland (*Euskal Herria*) in Spain and Europe and directed at the necessary democratic participation in the different organizations.
- *Block 5:* changes in time and an introduction to the learning of history, including content on the measurement of time and an approach to the conceptualization of historical time through the characterization of some societies in historical periods and relevant events and persons for the history of the Basque homeland and Spain.
- *Block 6:* matter and energy, including content on physical phenomena, substances, and chemical changes that will lay the foundations for subsequent learning and the rational use of resources.
- *Block 7:* objects, machines, and technologies, (a new feature) including information and communication technology literacy and others related to building devices with a previously established purpose based on knowledge of the basic properties of the components, with the intent of developing equal participation from girls and boys in the use of objects, machines, and technologies.

The unifying theme in the first year of **compulsory secondary education** is the diversity of matter, starting with a general vision of the universe and Earth's place within it, then studying the characteristics of animate and inanimate matter that makes up our planet. To manage the enormous diversity, especially in living beings, there is an attempt to find regularities to permit an initial classification of the diversity. The first year ends with an approach to the special nature of human beings from the perspective of their roots in society, nature, and the cosmos in general.

The focal point of the second year is changes in matter and the introduction of the concept of energy as the motor of these changes. Students also are provided with an initial qualitative explanation of these changes with a clearly global focus. In particular, changes on Earth are analyzed from the perspective of their relationship with Earth's external and internal energy. Finally, the study of the changes in living beings and the environment and the relationships between them provides an introduction to the study of ecological science.

Other criteria that have been taken into account in selecting and sequencing the conceptual, procedural, and attitudinal contents are the obligatory nature of the first 3 years, the different levels of students' cognitive development, the objective of favoring

gradual familiarization with scientific culture, and developing positive attitudes towards science and scientific work.

In all the courses, content relates to the ways science is built, experimental work, the language of science, and scientific attitudes toward learning about science. This is presented in a common block and, in some cases, with other blocks with closely related content. The common role is thus emphasized to the extent that the content relates equally to all the blocks and must be developed in a way that is as integrated as possible with the set of course content.

Instruction for Mathematics and Science in Primary and Lower Secondary Grades

Instructional Time

For knowledge of the natural, social, and cultural environment, the Basque Country's current curriculum establishes a minimum of 5 teaching hours a week in the first cycle of primary education (first and second years), another 5 hours in the second cycle (third and fourth years), and 4 hours in the third cycle (fifth and sixth years). Schools are responsible for managing these hours.

In compulsory secondary education, the minimum number of teaching hours for science is 7 hours a week in the first, second, and third years altogether. In the fourth year, there must be 2 hours each for the following subjects: biology, geology, physics, and chemistry. Schools are responsible for managing these hours.

Instructional Materials, Equipment, and Laboratories

Instructional materials, textbooks, etc. are chosen freely by the mathematics and science teachers at each school or educational center. There is no mandated or approved material.

Grade at Which Specialist Teachers for Mathematics and Science Are Introduced

Teachers must have a scientific or technological degree to teach the third and fourth grades of compulsory secondary education. In primary education and the first and second grades of compulsory secondary education, teachers must be qualified schoolteachers authorized to work in the areas of mathematics or science.

Use of Technology

Use of specific technologies within the classroom is not mandatory. Although the use of these technologies is voluntary, it is established that all areas must provide students with competence in information and communication technology.

Homework Policies

Giving homework is an option for each teacher or teachers' seminar at the schools and educational centers. Although it is not obligatory, it is a very common practice in the educational establishments.

Teachers and Teacher Education

Education and Training for Fourth and Eighth Grade Mathematics and Science Teachers

Teachers must be qualified or have a science or technology degree in order to teach mathematics and science in compulsory education (ages 6 to 16).

Teachers qualify after a 3-year course at the university and graduate after 5 years. However, this will change in 2009, when teachers will qualify after 4 years at the university, and graduates will need to study an additional 2 years to obtain a master's degree.

Currently, teachers in primary education and in the first cycle of compulsory secondary education who wish to teach mathematics and science must be qualified teachers and be authorized to teach science and mathematics. Science and mathematics teachers in secondary education must have a degree in a scientific-technological subject and have passed the Teaching Training Certificate (*Certificado de Aptitud Pedagógica*).

Teacher Professional Development in Mathematics, Science, and Technology

Teachers may, if they wish, attend training courses at their educational center or offsite.

Examinations and Assessments

National or Regional Examinations

In the Basque Country's compulsory education system, currently there are no external examinations or assessments outside the educational centers. Until recently, assessments in the Basque education system were assessments of the system, based on samples of students, which evaluated the main curricular areas. Of special importance to the bilingual system and society were the evaluations of levels B1 and B2 in the European Framework of Reference for the Basque language.

However, this situation is about to change in the 2008–2009 school year, when there will be annual diagnostic assessments of basic competencies for all students in the fourth cycle of primary education and the second cycle of compulsory secondary education. For the first time, there will be an assessment of all students at these two levels, and there will be a report for each school and each student. The aim is to diagnose annually whether students are acquiring the basic competencies defined in the areas of: science, technology, and health; learning to learn; mathematics; linguistic and communicative; information and digital; social and citizenship; humanistic and artistic culture; and personal autonomy and initiative.

Grade Promotion and Retention Policies

Under the grade promotion and retention policies, a student must repeat a year (unless, in exceptional circumstances, the teachers decide otherwise) when a student fails three subjects, but this may happen only once in the same grade and only a total of twice throughout the period of compulsory education. The percentage of students retained in any grade in the Basque Country is the lowest in Spain.

Suggested Readings

The Basque Education System: <http://www.isei-ivei.net/eng/noraeng/The%20Basque%20Education%20System.pdf>

The ISEI-IVEI website (in English): <http://www.isei-ivei.net/eng/indexeng.htm>

References

- 1 ISEI-IVEI stands for Irakas-Sistema Ebaluatu eta Ikertzeko Erakundea-Instituto Vasco de Evaluación e Investigación Educativa.
- 2 The Basque Country is an autonomous community and region of northern Spain, which has its own educational administration and policies.



British Columbia, Canada

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Introduction

Overview of Education System

In British Columbia, the Ministry of Education funds kindergarten to grade 12 education. Education services are delivered locally through boards of education, public schools, and independent schools, while the ministry provides leadership, develops policy and legislation, oversees system governance, sets curriculum learning standards, executes province-wide assessments, and builds accountability frameworks in partnership with boards of education.

In British Columbia, education is compulsory for children between the ages of 5 and 16. This includes 1 year of preprimary education (kindergarten) and 10 years of basic education. Schools are generally grouped into elementary (K–7) and secondary (grades 8–12). The K–12 system serves approximately 580,000 public school students, 69,000 independent school students, and 2,800 homeschooled children.¹

Language and Population

In British Columbia, every student is entitled to receive an education in English. Students who have a constitutional right to a Francophone education have the option of receiving an educational program provided in French.

Second-language Instruction

In 2007–2008, there were approximately 63,000 English as a second language students in British Columbia.² The Ministry of Education supports the principles of integration and inclusion of these students into the education system. Most of the prescribed learning outcomes for mathematics and science can be met by all students, including those with English as a second language needs. The Ministry of Education recognizes the importance of meeting the needs of these students and provides guidelines for teachers in *English as a Second Language Learners: A Guide for Classroom Teachers*.³

The mathematics and science curriculum also is offered in French for students enrolled in the French Immersion Program.

Emphasis on Mathematics and Science

One of the provincial government's goals is to make British Columbia the best educated and most literate jurisdiction in North America. The government has announced a series of initiatives for teachers, parents, students, and preschool children to help students gain the mathematics and literacy skills they need to succeed in school. In addition, a number of school districts have identified improving mathematics skills as a current goal.

Overarching Policies Related to Education and the Curriculum for Mathematics and Science

The aim of the mathematics program in British Columbia is to provide students with the opportunity to further their knowledge, skills, and attitudes related to mathematics. The Ministry of Education believes that a key component in successfully developing mathematics skills is making connections to the student's individual background and experiences.

The ministry supports the statement that advancements in science and technology play a significant role in everyday life. The ministry also subscribes to the vision that all students should have the opportunity to develop scientific literacy. It is anticipated that students will develop scientific literacy through achieving four key goals: An *understanding of science, technology, society, and the environment*; the *skills* required for scientific and technological inquiry; *knowledge* of concepts in various areas of science; and *attitudes* that support the responsible acquisition and application of scientific and technological knowledge to the mutual benefit of self, society, and the environment.⁴

The Mathematics Curriculum in Primary and Lower Secondary Grades*Summary of Curriculum Guides for Mathematics Through Eighth Grade*

The mathematics curriculum is prepared by the Ministry of Education and is distributed to all schools in Integrated Resource Packages, which contain the prescribed learning outcomes for students at each grade level, information on the philosophical framework upon which the curriculum is based, information on instruction and assessment, learning resources, and a glossary of terms. This mathematics information is consistent with *The Common Curriculum Framework for K–9 Mathematics*, developed by the Western and Northern Canadian Protocol (an agreement signed by ministers of education in Manitoba, Saskatchewan, Alberta, British Columbia, the Yukon Territory, and the Northwest Territories to collaborate on basic education, kindergarten to grade 12).⁵ The mathematics curriculum for K–7 contains the following four curriculum organizers.⁶

- **Number.** Students develop their concept of the number system and relationships between numbers.
- **Patterns and relations.** Students develop their ability to recognize, extend, create, and use numerical and non-numerical patterns to better understand the world around them. The patterns and relations organizer includes two suborganizers: (a) patterns and (b) variables and equations.
- **Shape and space.** Students develop their understanding of objects and shapes in the environment around them. The shape and space organizer includes

three suborganizers: (a) measurement, (b) 3-D objects and 2-D shapes, and (c) transformations.

- **Statistics and probability.** Students collect, interpret, and present data sets in relevant contexts to make decisions. The statistics and probability organizer includes two suborganizers: (a) data analysis and (b) chance and uncertainty.

In addition to the four curriculum organizers above, the curriculum for students in grade 8 also contains the following curriculum organizer.⁷

- **Problem solving.** Students use a variety of methods to solve real-life, practical, technical, and theoretical problems.

The Science Curriculum in Primary and Lower Secondary Grades

Summary of Curriculum Guides for Science Through Eighth Grade

As in mathematics, the science curriculum is prepared by the Ministry of Education and is distributed to all schools in Integrated Resource Packages, which contain the prescribed learning outcomes for students at each grade level, information on the philosophical framework upon which the curriculum is based, information on instruction and assessment, learning resources, and a glossary of terms. The science information has recently been revised to better reflect the content and philosophy of the Pan-Canadian Science Framework.⁸ The K–10 curriculum is broken down into four organizers.^{9,10}

- **Process of science.** Students learn skills such as observing, classifying, predicting, inferring, hypothesizing, scientific reasoning, critical thinking, and decision-making.
- **Life sciences.** Students extend their understanding of the living world and their place within it through the study of diversity, continuity, interactions, and the balance among organisms and their environments.
- **Physical sciences.** Students build a foundation for their understanding of the physical world through the study of matter and energy.
- **Earth and space sciences.** Students develop an understanding of the forces, processes, and dynamic life-supporting qualities of the Earth.

Instruction for Mathematics and Science in Primary and Lower Secondary Grades

Instructional Time

Instructional time for mathematics and science is not mandated in British Columbia. The Ministry of Education has published guidelines that recommend 30 percent of instructional time be spent on mathematics, science, and information and communication technology in grades 4–9, with integration of these skills into other subjects. There are no recommended time allocations for K–3.

Instructional Materials, Equipment, and Laboratories

The Ministry of Education provides lists of recommended learning resources for mathematics and science instruction at each grade level.¹¹ Recommended learning resources have undergone a provincial evaluation process using teacher evaluators and have the minister's order granting them provincial recommended status. These resources include print, video, software and CD-ROMs, games and manipulatives, and other multimedia formats.

The British Columbia science curriculum is activity based and provides an exciting method of teaching and learning, which includes experiments and demonstrations. Students are encouraged to complete labs using a variety of materials related to the topic being studied and write a lab report on the topic.

Use of Technology

It is the position of the Ministry of Education that the use of technology contributes to a learning environment that fosters the growing curiosity of students and leads to rich mathematical and scientific discoveries at all grade levels. The British Columbia mathematics curriculum views technology (e.g., calculators, computers, etc.) as a tool for developing conceptual understanding of mathematics, but students are still expected to develop strong mental mathematics skills through the development of personal strategies. While technology can be used in K–3 mathematics to enrich learning, it is expected that students will meet all outcomes without the use of technology. There are no specific recommendations for the use of technology in the mathematics curriculum in grades 4–8. The K–8 science curriculum does not require the use of technology (e.g., computers), but teachers may choose to integrate technology into their classes.

Teachers and Teacher Education

Education and Training for Fourth and Eighth Grade Mathematics and Science Teachers

To teach in the public or publicly funded independent schools of British Columbia, an educator must hold a Certificate of Qualification issued by the British Columbia College of Teachers. While the requirements in British Columbia are under review, teachers are currently required to have either 4 or 5 years of postsecondary education, which includes a degree and the completion of a teacher education program approved by the British Columbia College of Teachers. Elementary teachers (K–7) are required to have three credits of postsecondary science and three credits of postsecondary mathematics. Teacher education programs also require courses in the methods of teaching mathematics and science. Secondary science teachers (8–12) must have a major or a minor in a science that is taught in secondary schools, and secondary mathematics teachers must have a major or a minor in mathematics. Currently, secondary chemistry, physics, and mathematics teachers are in short supply in some districts, particularly in rural areas.

Teacher Professional Development in Mathematics, Science, and Technology

Professional development for teachers is provided by individual school districts. This can include professional development days, workshops, invited speakers, new teacher orientation and mentorship by experienced teachers, newsletters, and summer institutes. In addition, the Ministry of Education organizes an annual Teachers' Congress, which brings public, independent, aboriginal band schools (located on provincial reserves), and student teachers from across the province together to participate in a day-long dialogue with colleagues and the Minister of Education. The meeting helps to shape the future direction of education in British Columbia.

Examinations and Assessments

British Columbia students participate in three types of provincial examinations and assessments: the Foundation Skills Assessment, graduation program examinations (grades 10, 11, and 12), and optional grade 12 examinations.

The Foundation Skills Assessment is an annual, province-wide assessment that provides a snapshot of how well students in grades 4 and 7 are learning foundation skills in reading, writing, and numeracy. One purpose of the assessment is to help the province, school districts, and schools evaluate how well students are achieving basic skills and make plans to improve student achievement. A second purpose is to provide individual feedback to students and parents, which will pave the way for planning for students' needs in the subsequent year.

The graduation program examinations in grades 10, 11, and 12 are large-scale examinations designed to certify that individual students have met provincial graduation requirements in language arts, mathematics, science, and social studies. The examination mark makes up 20 percent of a student's final course mark and the school or classroom mark makes up the remaining 80 percent. In addition, optional grade 12 examinations are offered in mathematics, biology, chemistry, geography, geology, physics, history, English literature, French, and several foreign languages. If a student chooses to write an optional grade 12 examination, the examination mark makes up 40 percent of the student's final course mark, and the school or classroom mark makes up the remaining 60 percent. Some postsecondary institutions may require students to write optional grade 12 examinations for admission requirements.

Other Tests

British Columbia participates in one national assessment: the Pan-Canadian Assessment Program, which assesses the reading, science, and mathematics knowledge and skills of 13- and 15-year-old students. British Columbia participates in three international assessments: IEA's TIMSS and PIRLS and OECD's Programme for International Student Assessment.

Individual school districts or schools also may use standardized commercial tests to evaluate students' learning, such as the Canadian Cognitive Abilities Test, the Canadian Test of Basic Skills, and the Canadian Achievement Test.

Monitoring Individual Student Progress

Teachers document student progress through report cards, which indicate the student's performance based on the provincial curriculum, areas in which the student may require further attention or development, and ways of supporting the student in his or her learning and behaviors.¹² Teachers also use students' results on provincial assessments to monitor their progress.

Grade Promotion and Retention Policies

In British Columbia, policies regarding student promotion and retention are made at the district level. In general, students in the primary years (K–3) do not repeat a grade, while in grades 4–12, retention may occur under special circumstances if parents and teachers find that retention is in the student's best interest.¹³

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Dubai, United Arab Emirates

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Introduction

Overview of Education System

The United Arab Emirates (UAE) offers a full-fledged education system for boys and girls from kindergarten to higher education, with education for the country's citizens provided free of charge through government schools, colleges, and universities. There also is an extensive private education sector, accounting for approximately 40 percent of the student population. Education from the primary to upper middle school level is universal and compulsory and literacy rates are comparable to the norm in developed countries.¹ In the emirate of Dubai, where TIMSS was introduced in 2007, more than 85 percent of students are enrolled in private schools.²

The Ministry of Education acts as the policy and regulations provider for both public and private schools, as well as the supplier of services for public schools. For instance, the ministry is responsible for designing school administration structure, staff recruitment and compensation, curriculum design and improvement, and the availability of resources. Hence, the role of public schools in terms of administrative responsibility is limited to ensuring that the ministry's policies and standards are well observed.³

During the past 2 years, independent educational boards were founded in four emirates allowing their regional schools a considerable degree of autonomy in alliance with the general policy of the ministry. In Dubai, for example, the Knowledge and Human Development Authority was established to develop all knowledge and human resource sectors in the emirate. The goal of this organization is to ensure the continuous development of the education sector and improve the quality and outcomes of education on all fronts and at all stages.⁴ The establishment of such boards stimulates the development of education in the country and promises constructive reform of the education system. At the same time, a significant reform took place at the school level with the launching of *Al Ghad* schools (schools of tomorrow). The *Al Ghad* schools program began with a cohort of 50 schools, and others were added in subsequent years. In these schools, a new curriculum in English was introduced in grades 6, 10, 11, and 12,

with science and mathematics to follow in subsequent years. In grade 1, schools will integrate the teaching of English with mathematics and science, which will be taught in English. Graduates of *Al Ghad* schools will be fully bilingual, knowledgeable about their rich culture and heritage, educated in an active learning environment, skilled in the use of information technology, soundly grounded in mathematics and science, and prepared for higher education, successful careers, healthy lives, and parenthood, all within a global context.⁵

Language and Population

The population of the UAE is estimated to be around 4 million, with a significant annual growth rate. UAE citizens account for a little less than 20 percent of the population, with the remainder coming from the rest of the Arab world, the Indian subcontinent, the Far East, Europe, and elsewhere. The national language is Arabic, although English and several Asian languages are used widely, particularly in commerce. Islam is the state religion. The main population centers are the cities of Abu Dhabi (the capital) and Dubai.⁶

Overarching Policies Related to Education and the Curriculum for Mathematics and Science

The Dubai Strategic Plan is based on interest in improving the quality of education so that it will meet global standards. Recently, the Dubai Inspection Bureau was launched to define and measure education quality in order to support the improvement of education in Dubai. The bureau is expected to provide comprehensive information on the standard of education in Dubai, which will inform improvement planning at the school and policy level.⁷

The Mathematics Curriculum in Primary and Lower Secondary Grades

Summary of National Curriculum Guides for Mathematics Through Eighth Grade

To ensure that the mathematics curriculum⁸ is up to date and meets the needs of different students through the 12 years of schooling in the UAE, the ministry, in collaboration with other Arabian Gulf countries, recently has designed a mathematics curriculum, taking into account many factors that are fundamental in today's education norms and values. The development of the mathematics curriculum was based on a number of basic elements. These include the need to observe Islamic and social values and fulfill educational policy standards that will achieve the goals of the Dubai Strategic Plan and a desire to embrace new trends, including the use of modern technology in the teaching and learning of mathematics. In short, the mathematics curriculum was built on philosophical, social, psychological, and knowledge bases.

To maintain the quality of teaching and learning in mathematics, certain standards must be considered in the curriculum. The mathematics curriculum should do the following.

- Build on a full understanding and comprehension of mathematics concepts through a series of exercises that allow students to apply these concepts in daily life activities. A well-designed time schedule is essential so that all or most

students acquire full knowledge of the concepts and good training in their application.

- Encourage positive and practical interaction for students. This is to be achieved by providing a positive educational environment that produces ideas and allows them to be absorbed through discussion, experiments, and implementation. Advanced technology and tools are vital elements of such an environment.
- Emphasize the ability to think critically and solve problems.
- Draw attention to the practical side of mathematics as a vibrant subject with many benefits.
- Have variety and comprehensiveness, actively linking mathematics to other school subjects.
- Encourage students to utilize advanced technology and modern mathematics tools consistently and at all school levels as an educational means.

The school mathematics curriculum is designed around 10 major topics: numbers and operations, algebra and functions, geometry, measurement, data analysis and probabilities, problem solving, reasoning and proof, communication, connection, and representation.

The first five topics are the mathematical concepts and skills that students should learn at all school levels from grade 1 through grade 12, while the last five topics are aimed at equipping students with skills they can apply to other subject areas and in their daily life activities.

The Science Curriculum in Primary and Lower Secondary Grades

Summary of National Curriculum Guides for Science Through Eighth Grade

With the rapid development in science and technology, there is a growing need to develop highly qualified UAE nationals equipped with scientific knowledge and skills in order to cope with the consistent changes in the field that impact modern life. To achieve this goal, the science curriculum⁹ is carefully designed and continuously improved. Every 10 years, the science curriculum is rewritten. The bases for developing the curriculum are the same standard bases mentioned in the mathematics section. The development of the science curriculum is based on the science curriculum of other nations that are more advanced in the field.

General standards for teaching and learning science include integrated concepts, science as a means of research and discovery, different science aspects (physics, chemistry, biology, and earth and space science), the connection between science and technology, personal and social views on science, and the history and nature of science. Students are encouraged to learn how to analyze systems, classify and categorize, interpret and introduce evidence-based theories and learn about the variation between stable and consistently changing subjects, and understand the different functions of living and nonliving objects.

By the end of **grade 5**, students are expected to learn different aspects of science as they relate to the standards mentioned earlier.

- In **biology**, students should be familiar with the structure of cells as a constructive unit of living creatures, organs of the human body, and animals and their functions. They should be able to describe different features of animals and plants, present life cycles for some animals, and describe the food chain. In addition, they should understand the similarities and differences between growing and adult animals and the effect of different environments on different species.
- In **physics and chemistry**, students should be able to address the different forms of objects and their physical features, explore the features and uses of magnetism, and understand static electricity and its impact on life. They also should recognize the features and uses of light and sound and learn about where energy comes from and how it is transmitted and sustained. They should understand the impact of different forces on different things, the work of basic tools and engines, and the relationship between volume, power, and motion. They should learn about the impact of heat on different forms of objects and its application and the features of water and air and their significance for life.
- In **earth and space science**, students should be familiar with natural sources and sustaining them and understand the geological nature of the country and some of the natural phenomena. They should recognize the components of the Earth and learn the difference between the sun, stars, and planets and their movement in the galaxy.
- In **science, nature, and history**, students recognize the contribution of past scientists, whether male or female, from all over the world and the foundations that form modern science.
- In **scientific survey operations**, students learn how to find solutions and answers for scientific issues, develop their skills in critical thinking and interpretation, and use evidence-based proofs and creative thinking.
- In **science and technology**, students learn how to use modern technology in conducting scientific research and presenting scientific facts using computers.
- In **science from personal and social perspective**, students are trained to be accountable for their own health status, express the positive aspects of the surrounding environment, and appreciate technical and manual jobs.

By the end of **grade 9**, students are expected to learn different aspects of science in the standards that were mentioned earlier.

- In **biology**, students explore the living cell and its structure and types, study reproduction in all living creatures, recognize genetics and their transformation over generations and understand the impact of the surrounding environment on genetic features.

- In **physics and chemistry**, students elaborate on the basic science knowledge and skills that they learned in primary school. In addition, they learn about the atom and the chemical form of objects, recognize the physical and chemical features of objects, and design models of some engines and understand how they work. They learn advanced applications for magnetic power, electricity, light and sound, and discover the causes of some tools and engines that do not function.
- In **earth and space science**, students elaborate on the facts they learned in primary school, are encouraged to explore natural phenomena, find answers about matters like the impact of time on Earth's components, and find out about the age of rocks.
- In **science, nature, and history**, students continue to learn about past contributions and realize the importance of sharing and discussing scientific findings with other nations and the significance of authenticating scientific experiments and explorations.
- In **scientific survey operations**, students are trained to follow a scientific method in their research where they learn how to find answers, evaluate and improve their findings, and debate their concepts of possible outcomes.
- In **science and technology**, students learn to utilize modern technology in designing and projecting their work and are encouraged to research further on the Internet.
- In **science from a personal and social perspective**, students understand how to maintain good health and discuss relevant issues.

Instruction for Mathematics and Science in Primary and Lower Secondary Grades

Instructional Time

In the UAE public schools, the ministry dictates the number of hours spent on each subject. Students in grades 1–5 have approximately 54 hours of science instruction during the academic year, with a total of three lessons per week, each lesson being 40 minutes. In mathematics, they have approximately 108 hours of instruction, with a total of six lessons per week, each being 40 minutes. Students in grades 6–9 have approximately 80 hours of science during the academic year, with a total of four lessons per week, each 45 minutes. Mathematics at these grades involves 120 classroom hours during the year, made up of six 45-minute lessons per week.¹⁰

Exhibit 1 shows the distribution of the major science topics and time allocated in an ideal school year.

Exhibit 1 Yearly Instructional Time in Science in Dubai

Topic	Grades 1–5		Grades 6–9	
	Topic Weight (%) of Total Science	Topic Time (Hours/Year)	Topic Weight (%) of Total Science	Topic Time (Hours/Year)
Biology	35	18.67	30	24.75
Physics & Chemistry	35	18.67	45	36
Earth & Space Science	30	16.67	25	18.75
Total Science Hours/Year		54		79.5

Instructional Materials, Equipment, and Laboratories

In the UAE public schools, the curriculum in mathematics and in science tends to be very structured and relies heavily on textbooks provided by the ministry. No further resources are utilized by students, but the ministry also recommends a list of resources for teachers to use. For mathematics in grades 1–3, the ministry equips schools with an adequate supply of supplementary resources and educational games; however, these resources seem to be less available as students move to the upper grades. The ministry supplies schools with a number of science laboratories, each to be used for a specific area of science. The materials available at these laboratories are insufficient for comprehensive experiments to be conducted by all students, therefore teachers often conduct them while students watch and take notes.¹¹

For mathematics, student textbooks are comprised of chapters that are specified in the National Mathematics Syllabus for each grade, produced in Arabic only in grades 1 to 5 and in both Arabic and English in grades 6 to 12. Each chapter relates to a specific standard and contains material for presentation of the learning point with any accompanying photos and drawings. These are followed by practice exercises, which include examples and solutions that take into account different abilities of students and other exercises and applications, which challenge students further. Finally, at the end of each lesson, there is a learning activity. Statistical data that are mentioned in the book are realistic and reflective of the local environment, and if there is a need to use external data, they are selected to be consistent with the culture and customs of society and taken from reliable resources. Guidance and direction are provided to the parents or guardians so as to clarify their role in monitoring and promoting the education of their children. These are available at the beginning of each chapter or at the end of each lesson, especially in grades 1 to 5.

The content of the science textbook is carefully selected from various international resources. The criteria of selection are the feasibility of the chosen topics for each grade to meet students' abilities; relationship to local social and cultural contexts; correlation with the science textbooks of the previous and following grades; alignment with other subjects' textbooks; and present, updated, and authenticated scientific facts and concepts. Activities and practical experiments are doable in terms of practicalities and within the constraints of time and resources. They also should encourage teamwork and cooperative learning and an enthusiasm for scientific research.

Grade at Which Specialist Teacher for Mathematics and Science Are Introduced

All public schools in the UAE have specialized teachers who teach both mathematics and science. Beginning in grade 4, schools have separate subject area specialist teachers for mathematics and science. Secondary schools (grades 10–12) have different teachers for each of the science areas—physics, chemistry, biology, and geology.¹²

Use of Technology

Students' use of technology in public schools is relatively infrequent, and the technology does not yet meet the Dubai Strategic Plan standards. Schools have started using email for their formal communications, and the majority of teachers have responded positively to a ministry recommendation to obtain the International Computer Driving License. Further, the ruler of Dubai launched an advanced information and communication technology (ICT) program for secondary schools in 2000. This program has successfully run up-to-date training in the ICT applications needed by the modern job market. This interest in ICT tends to be less prevalent in early public education. Each classroom is supplied with only one computer, and the computer laboratory is used exclusively for the teaching of ICT, rather than being integrated into other subject areas. Calculators are widely used beginning at grade 4, and students are introduced to more complicated technology as they move to the upper grades.¹³

Homework Policies

Teachers' books provide a general scheme for homework, but the nature of homework is left to teachers' judgment. Generally, students in grades 1 to 5 do a minimum of two homework assignments for mathematics and one for science per week, and the amount continues to increase as students move to the upper grades. From grades 1 to 11, homework is 10 percent of the mark students receive on their progress report.¹⁴

Teachers and Teacher Education

Education and Training for Fourth and Eighth Grade Mathematics and Science Teachers

To become a teacher in the UAE, on average, it is necessary to complete 4 years of studies at a university in one of two paths: an education college or a specialized college. In a college of education, a student can specialize in a specific subject area, but since the majority of studies are on educational and pedagogical concepts, the graduate only can teach grades 1 to 6, whereas a graduate from a specialized college can teach all grades and is usually appointed to teach at middle or secondary schools. Graduates of specialized colleges have to receive some teacher training, arranged exclusively by the ministry, before they start teaching.¹⁵

The qualifications and conditions of teaching differ whether the candidates are UAE nationals or non-nationals. This variation is mainly in number of years of experience required and in compensation. All candidates must be university graduates and hold bachelor's degrees in the subject area for which they apply.

National candidates are not restricted by a minimum GPA average, while non-nationals should obtain at least an average of a "C", except in the case of those who hold

educational diplomas and higher degrees. Non-national candidates should not exceed age 40 and have no less than 2 years of teaching experience, while the nationals' age criteria are subject to the Civil Service Bureau rules and regulations. In regard to job placement, nationals have priority. Priority in teaching appointments goes to holders of the International Computer Driving License and a certificate in the Test of English as a Foreign Language or the International English Language Testing System.

After the applications are compared against the initial requirements, candidates have to be interviewed by a group of subject supervisors and school principals. Each candidate is assessed on subject knowledge (40 marks), pedagogical competence (25 marks), personal competencies (15 marks), and communication skills (20 marks). Candidates should have a minimum of 60 out of 100 marks to pass the assessment.

Teacher Professional Development in Mathematics, Science, and Technology

Graduates of education colleges complete significant periods of practical experience as a fundamental part of their studies. At some colleges, they devote several weeks each semester to training in schools (Student Teacher Program), while in other colleges, they allocate the final semester for this purpose. This is why education college graduates do not receive any further training once they are placed in a teaching job. However, they do receive other general training not designated for beginner teachers. These graduates only teach grades 1 to 6 because their studies are primarily around pedagogical concepts and not very rich in applied sciences.

Examinations and Assessments

National or Regional Examinations

According to the UAE education system, students should pass at least the midyear and end-of-year examinations to be eligible to move to the upper grades (grades 10–11) or to enroll in higher education (grade 12). Students who fail a maximum of three subjects must retake the tests during the summer holiday and pass all of them in order to be promoted to the upper level. The end-of-year assessments are integrated across each educational zone (in the UAE, each emirate has a separate educational office, and all of them are linked to the ministry).¹⁶

Most of these examinations are still in written form and only a few require practical applications. However, the ministry built a systematic model to ensure proper testing for every student. This model was constructed from six bases: consistent evaluation, maintenance of the assessment purpose, comprehensiveness of the topics covered in the assessment, use of proper assessment methods, observation of the assessment setting and time and place, and individual student's needs. The outcomes of the assessment should give real indicators of what students learned. The Center of Curriculum Development at the ministry encourages teachers to provide feedback on the evaluation processes of curriculum-based issues.

Monitoring Individual Student Progress

As teachers are responsible for day-to-day student evaluation, they are expected to examine the outcomes of different assessments in order to improve the learning level. An essential part of the ongoing assessment model requires that teachers encourage students to engage in self-evaluation or peer evaluation. Progress reports on student attainment are sent to parents, as well as to the school administration and regional education board on a regular basis for follow-up on students' progress and to preserve a tracking record of their achievement.

Grade Promotion and Retention Policies

As mentioned previously, students must pass two examinations—midyear and end-of-year—and pass all subjects to be promoted to the next grade.

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Massachusetts, United States

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Introduction

Overview of Education System

The Massachusetts Board of Elementary and Secondary Education and the Massachusetts Department of Elementary and Secondary Education are responsible for statewide education policy decisions in grades K–12. The education system is decentralized with a district school committee responsible for overseeing the local public schools. Elected by the voters of a school district, school committee members control the budget, negotiate teacher union contracts, and set policies for the public schools in that district. The school committee hires a superintendent who is the head administrator. He or she is responsible for running the schools in the district and reports directly to the school committee.¹

Massachusetts does not have a statewide curriculum for any subject, and each district may select its own instructional curriculum and materials. However, all Massachusetts public schools are expected to teach the curriculum based on the academic content standards in the Massachusetts Curriculum Frameworks. The state has developed curriculum frameworks in seven content areas: the arts, English language arts, foreign languages, comprehensive health, mathematics, history and social science, and science and technology/engineering.² All students, including students with disabilities and students with limited English proficiency, are expected to receive instruction based on the standards in the curriculum frameworks.³ Decisions about tracking are made at the local level.

During the 2006–2007 school year, there were 1,875 public schools in Massachusetts, including 1,189 elementary schools (grades K–5), 328 middle schools (grades 6–8), and 344 high schools (grades 9–12), with an enrollment of 968,661 students.⁴ In 2003, there were 134,827 students enrolled in private schools in grades K–12.

A free public school education is offered to students in kindergarten through grade 12. School attendance is legally mandated for children between the ages of 6 and 16.^{5,6} School systems are required to operate kindergartens, but children are not required to attend

them. According to state regulations, a child who has turned 6 years of age must be enrolled in school (first grade) by the September following that birthday.⁷

Preprimary education addresses the physical, social, educational, and moral development of young children. The Massachusetts Department of Early Education and Care is the lead agency for all early education and care programs and services.⁸

There are 389 public school districts in Massachusetts. A public school district consists of one or more public schools operated under the supervision of an elected or appointed school committee and a superintendent. Some public school districts are regional school districts that are made up of member towns and governed by a regional school committee, and charter schools, which are independent public schools that operate under 5-year charters granted by the Massachusetts Board of Elementary and Secondary Education.⁹

Some public school districts are educational collaboratives, which are formed through an agreement among two or more school committees to provide educational programs or services for their member schools systems. Classified as school districts, there are currently 32 educational collaboratives in Massachusetts.

Some public school students are served by private special education schools. These schools are private institutions that serve students with disabilities when it has been determined that their needs cannot be accommodated locally.

Language and Population

English is the official language of instruction in Massachusetts. In 2005, Massachusetts public schools reported 49,923 limited English proficient students with 112 different primary languages. Most English language learners receive sheltered English immersion instruction while pursuing their regular studies.¹⁰ The most common non-English languages spoken by public school students in the state are Spanish, Portuguese, Khmer, Cape Verdean Creole, Vietnamese, Chinese, Russian, Arabic, and Korean.

White (non-Hispanic) students represent 71.5 percent of public school enrollments in Massachusetts. The second largest racial/ethnic group is Hispanic/Latino (13.3%) followed by African American (8.2%).¹¹ During the 2006–2007 school year, the Massachusetts Department of Education reported statewide test scores according to the following racial/ethnic groups: African American/Black, Asian, Hispanic/Latino, Native Hawaiian/Pacific Islander, Multi-Race, Non-Hispanic/Latino, Native American, and White.¹²

Emphasis on Mathematics and Science

Federal and state funds support the following mathematics and science programs in Massachusetts.¹³

- *Massachusetts Mathematics and Science Partnership Program* (U.S. Department of Education, Title II B):¹⁴ provides professional development in mathematics and science for high-need school districts and higher education institution partnerships.

- *Teacher Quality Grants* (U.S. Department of Education, Title II A):¹⁵ provide teacher professional development in mathematics and science.
- *Math and Science Teacher Development and Assessment Program*: provides teacher professional development in mathematics and science and teacher assessment in mathematics.
- *Math and Science Teacher Scholarship Program* (Board of Higher Education): provides professional development scholarship assistance in mathematics and science to teachers who are currently employed in Massachusetts public schools, but have received waivers from certification regulations or are teaching outside their certificate area.
- *STEM Pipeline Fund* (Board of Higher Education): provides funding for five regional centers to support math and science career development and professional development in fields related to mathematics, science, technology, and engineering.
- *The Massachusetts Academy for Mathematics and Science*: a high school in central Massachusetts that serves approximately 100 students.

The Mathematics Curriculum in Primary and Lower Secondary Grades

Summary of National Curriculum Guides for Mathematics Through Eighth Grade

The following is an overview of the mathematics curriculum in the **primary grades (K–5)**.¹⁶

Number sense and operations involves problem solving, communicating, reasoning, and connecting. Students are taught to count, compute, read, model, write, and interpret whole numbers to at least 100,000 and decimals between 0 and 1 up to the hundredths place. Students should be able to demonstrate an understanding of the values of the digits in a base 10 number system; compare and order the numbers while they learn different meanings and relationships of the operations (+, −, ×, ÷). Addition and subtraction involve up to five-digit numbers, and multiplication involves up to three digits by two digits. Division is computed up to a three-digit whole number with a single-digit divisor, with any remainders interpreted. Students are expected to select and use a variety of strategies to estimate quantities, measures, the results of whole-number computations up to three-digit whole numbers, and amounts of money to \$1,000. After students have learned how to use the conventional algorithm for an operation, they are expected to explain their method and understand that many methods exist. Students are expected to demonstrate an understanding of fractions as parts of unit wholes, as parts of a collection, and as locations on the number line. Students are taught to use concrete objects or visual models to add and subtract common fractions.

Students are expected to acquire and deepen their understanding of **patterns, relations, and algebra** and work informally with the concept of function. Students are encouraged to use mathematical representations to identify, describe, translate, and extend repeating rhythmic, verbal, and visual patterns. They are taught to recognize

patterns and relationships among objects, and sort and classify them, observing similarities and differences. They then are expected to probe more deeply into the study of patterns as they explore the properties of the operations of addition and multiplication. The concept of a variable is developed and applied in equalities and inequalities and through practical situations. Students are taught to solve problems involving proportional relationships, including unit pricing and map interpretation. They are asked to determine how a change in one variable relates to a change in a second variable.

Geometry involves exploring shapes and the relationships among them. Students are asked to identify the components, attributes, and properties of different two- and three-dimensional shapes, including sides, corners or vertices, edges, interiors, and exteriors. They are expected to develop procedures to identify and categorize shapes, angles, lines, and line segments by referring to their components, attributes, and properties. Students are asked to investigate these features dynamically by using mirrors, paper folding, hand drawing, and computer drawings. Still operating on concrete objects, students are expected to develop the idea of transformations by recognizing and predicting changes brought about by slides, flips, and turns on both individual objects and combinations of objects. Investigations of simple transformations lead to the concept of congruence.

Building on existing **measurement** ideas, students are expected to demonstrate an understanding of attributes such as length, area, weight, and volume and select the appropriate type of unit for measuring each attribute. They are asked to carry out simple unit conversions within a system of measurement (e.g., hours to minutes, cents to dollars, yards to feet or inches). Students are taught to use estimation to predict and validate the results. They are asked to solve problems involving length, area, volume, weight, time, angle size, and temperature using diagrams, models, or grids or by measuring using the appropriate metric and English units and tools.

In their study of **data analysis, statistics, and probability**, students are asked to collect data, observe patterns in the data and organize and analyze the data to draw conclusions. To organize and display their data, they are encouraged to begin by using concrete and pictorial representations, such as tables, lists, bar graphs, pictographs, line graphs, line plots, circle graphs, and tallies. They are expected to use their representations to draw conclusions and make predictions from various data sets. Students classify outcomes as “certain,” “likely,” “unlikely,” or “impossible” by designing and constructing experiments using concrete objects such as counters, number cubes, spinners, or coins.

The following is an overview of the mathematics curriculum in the **lower secondary grades (6–8)**.¹⁷

In middle school, **number sense and operations** center on understanding numbers, ways of representing positive and negative numbers, and relationships among numbers and number systems. Students are expected to compare, order, estimate, and translate among integers, fractions, and mixed numbers, rational numbers, decimals, percents, and frequently used irrational numbers (π , $\sqrt{2}$). They are asked to represent numbers using a variety of methods including scientific notation and prime factorization. Students should be able to achieve competence with rational number computations and the application

of the order of operations rule, including the understanding and use of positive integer exponents and square roots. They are asked to demonstrate an understanding of absolute value, the properties of identity, and inverse elements and appropriately use the associative, commutative, and distributive properties to solve problems. In addition, students are asked to use ratios and proportions to solve problems.

At this level, work with **patterns, functions, and algebra** progresses in mathematical sophistication. Students are expected to learn that change is a central idea in the study of mathematics and that multiple representations are needed to express change. They are asked to identify, represent, and analyze numerical relationships in tables, charts, and graphs and learn about proportional reasoning. Students are taught to integrate geometry and measurement into their solutions of proportions and ratios and build on prior experiences as they compare sequences and functions represented in recursive and explicit forms. They are expected to use linear equations and graphs to model and analyze problems. They learn to identify the slope of a line as a measure of its steepness and as a constant rate of change from its table of values, equation, or graph. They are expected to apply the concept of slope to the solution of problems. Students are asked to explain and analyze both quantitatively and qualitatively how a change in one variable results in a change in another variable in functional relationships.

In eighth grade, students are expected to solve problems in other areas of mathematics using concepts of **geometry**, including coordinate geometry, perspective drawings, and projections of three-dimensional objects. They are asked to use mechanical and electronic tools to construct common geometric shapes and patterns and to develop the idea of geometric similarity, which can be integrated with the ideas of ratio and proportion. In addition, students are expected to apply methods developed in the geometric context to make sense of fractions and variables, construct graphs and other representations of data, and make and interpret maps, blueprints, and schematic drawings. They are taught to apply the Pythagorean theorem to solve problems.

Students are expected to apply knowledge of **measurement** to understand attributes of objects and the units, systems, and processes of measurement by selecting and applying appropriate techniques, tools, and formulas to determine measurements. They are asked to convert and use appropriate units of measurement or scale within the same system of measurement, including those of area and perimeter/circumference of parallelograms, trapezoids, and circles. Given the formulas, students are expected to determine the surface area and volume of rectangular prisms, cylinders, and spheres.

In their study of **data analysis, statistics, and probability**, students shift their perspective from viewing data as a set of individual pieces of information to understanding data as a coherent set with its own collective properties. Students are asked to study characteristics of sets of data, including measures of central tendency and techniques for displaying these characteristics (e.g., stem-and-leaf plots and scatterplots). Students are expected to learn how to select and construct representations most appropriate for the data and how to recognize and avoid misleading and inappropriate representations.

The Science Curriculum in Primary and Lower Secondary Grades

Summary of National Curriculum Guides for Science Through Eighth Grade

The following is an overview of the science curriculum in the **primary grades (K–5)**.¹⁸

Earth and space science focuses on the following six subtopics: rocks and their properties; soil; weather; the water cycle; Earth's history; and Earth in the solar system. Students are expected to explore properties of geological materials and how they change. They are asked to conduct tests to classify materials by observed properties, make and record sequential observations, note patterns and variations, and look for factors that cause change. Students are expected to observe weather phenomena and describe them quantitatively using simple tools. Students are exposed to a study of the water cycle and the properties of soil and how it is formed. Students are asked to trace Earth's history through the examination of changes to the Earth's surface. They are expected to recognize that Earth is a part of the solar system.

Expectations for student learning in **life science** are organized into four subtopics: characteristics of plants and animals, structures and functions, adaptations of living things, and energy and living things. Students are asked to record details of the life cycles of plants and animals and to explore the way organisms are adapted to their habitats. They classify plants and animals according to shared physical characteristics. Students are expected to describe how the sun's energy is used by plants and transferred within a food chain and be able to differentiate between the properties of objects and properties of materials.

The topics students are expected to learn in **physical sciences** fall within chemistry and physics. The standards from those subjects are organized into three subtopics: properties of objects and materials, states of matter, and forms of energy (including electrical, magnetic, sound, and light). Students are expected to be able to compare and contrast solids, liquids, and gases. Their study of the different forms of energy includes electrical circuits, magnetic polarity, the production of sound by vibration, and how light travels.

The learning standards in **technology/engineering** are organized into two subtopics: engineering design and materials and tools. Students are expected to identify materials used to accomplish a design task based on the materials' specific properties and explain which materials and tools are appropriate to construct a given prototype. They are expected to achieve a level of engineering design skill by recognizing a need or problem, learning different ways that the problem can be represented, and working with a variety of materials and tools to create a product or system to address the problem.

The following is an overview of science curriculum in the **lower secondary grades (6–8)**.¹⁹

Students explore **Earth and space science** within the following five subtopics: mapping the Earth; Earth's structure; heat transfer in the Earth system; Earth's history; and Earth in the solar system. Students are expected to gain sophistication and experience in using models, satellite images, and maps to represent and interpret processes and features. They are expected to recognize that many of Earth's natural events occur because

of processes such as heat transfer. In addition, students are expected to recognize the interacting nature of Earth's four major systems: the geosphere, hydrosphere, atmosphere, and biosphere. Ideally, students begin to see how Earth's movement affects both the living and nonliving components of the world. Students are expected to gain an understanding of the place of Earth in the solar system and changes in Earth's composition and topography over time.

Students are expected to acquire a body of knowledge in **life science** within the following subtopics: classification of organisms, structure and function of cells, systems in living things, reproduction, and changes in ecosystems over time. Students begin to study biology at the microscopic level, without delving into the biochemistry of cells. They are expected to learn that organisms are composed of cells and that some organisms are unicellular and must therefore carry out all of the necessary processes for life within a single cell. Students are taught to observe that the cells of a multicellular organism can be physically very different from each other and relate that fact to the specific role that each cell has in the organism (specialization). They should be able to distinguish between sexual and asexual reproduction in the passing of an organism's traits from generation to generation. At the macroscopic level, students are expected to learn the systems of the human body in a general way. They learn to develop the understanding that the human body has organs and that these organs together create systems that interact with each other to maintain life.

Students also focus on the interactions that occur within ecosystems. They are asked to examine the hierarchical organization of multicellular organisms and the roles and relationships that organisms occupy in an ecosystem. Genetic variation is explored along with the environmental factors that cause evolution and diversity of organisms. Students are expected to recognize that biological evolution accounts for the diversity of species developed through gradual processes over many generations. They are asked to explore the interdependence of living things, specifically the dependence of life on photosynthetic organisms such as plants. Students are expected to use mathematics to calculate rates of growth, derive averages and ranges, and represent data graphically to describe and interpret ecological concepts.

In the **physical sciences**, subtopics include properties of matter, elements, compounds, and mixtures; motion of objects; forms of energy; and heat energy. Physical-world experiences help students develop concepts associated with motion, mass, volume, and energy. They are expected to study volume and mass in an effort to define density. Students are asked to differentiate between mixtures and pure substances and give basic examples of elements and compounds. The difference and transformation between potential and kinetic energy is explored. Students are expected to study the movement of heat resulting in temperature changes, phase changes, and the equilibrium between warm and cool objects.

In **technology/engineering**, the focus is on engineering questions and technological solutions that emphasize research and problem solving. Students are expected to explore engineering design; materials, tools, and machines; and communication, manufacturing,

construction, transportation, and bioengineering technologies. They are asked to identify and understand the five elements of a technology system (goal, inputs, processes, outputs, and feedback). Students are asked to conceptualize a problem, design prototypes in three dimensions, and use tools to construct their prototypes, test their prototypes, and make modifications as necessary. Students are expected to communicate their ideas through engineering drawings, written reports, and pictures. They develop an understanding of how raw materials are converted to physical goods. Students study construction technologies that lead to structures for shelter, manufacturing, transport, and recreation. Students are expected to learn the basic elements of transportation systems and bioengineering technologies that will improve health and/or contribute improvements to our daily lives.

Instruction for Mathematics and Science in Primary and Lower Secondary Grades

Instructional Time

Elementary school students must receive a minimum of 900 hours of instructional time per school year, and secondary students must receive a minimum of 990 hours of instructional time per school year. The amount of instructional time devoted to teaching mathematics and science is determined at the local level. Massachusetts schools must be in session at least 180 days per school year.²⁰

The School Redesign: Expanded Learning Time²¹ initiative is intended to support districts' activities in planning for longer school days, a longer school year, or both, as part of a redesign strategy to raise student achievement. Currently 18 schools in eight districts are operating redesigned schools with expanded learning time.

Instructional Materials, Equipment, and Laboratories

As stated previously, Massachusetts does not have a statewide curriculum for any subject, and each district may select its own instructional curriculum and materials, including textbooks. Local school districts are responsible for school building equipment.

Grade at Which Specialist Teachers for Mathematics and Science Are Introduced

Decisions on hiring staff are made at the local level. Many districts employ specialist teachers at the middle school level. All students have specialist teachers at the high school level (grades 9–12).²²

Use of Technology

The *Massachusetts Recommended Pre-K Instructional Technology Standards*,²³ published in 2001, defines what students should know and be able to do in order to be technologically literate. The standards recommend learning technology skills within the context of the curriculum. The Massachusetts Department of Education's Local Technology Plan Guidelines²⁴ recommend that districts maintain a ratio of fewer than five students per high-capacity computer. In the 2005–2006 school year, the ratio of computers to students was reported at approximately 1:4. According to surveys submitted to the Massachusetts

Department of Education by districts in 2006, 41 percent of teachers used technology nearly every day, 32 percent used technology about once a week, 16 percent used technology about once a month, and 10 percent used technology rarely or never.

Regarding calculator use, districts are required to make calculators available to students for use on selected sessions of the statewide tests beginning in grade 7. Calculators also are provided to students taking high school end-of-course tests in chemistry, introductory physics, and technology/engineering.²⁵

Homework Policies

Homework policies are established at the local level.

Teachers and Teacher Education

Education and Training for Fourth and Eighth Grade Mathematics and Science Teachers

To earn an initial teaching license in Massachusetts,²⁶ a candidate must have a bachelor's degree, pass the Communication and Literacy Skills Test and a test on the subject matter that will be taught, complete an approved educator preparation program, and present evidence of sound moral character.

To advance to a professional teaching license,²⁷ the candidate must complete a 1-year induction program with a mentor, complete at least 3 full years of employment under the initial license, have at least 50 hours of mentored experience beyond the induction year, and complete a master's level graduate program (or equivalent).

Teacher Professional Development in Mathematics, Science, and Technology

Massachusetts has a recertification process that requires all educators to prepare an Individual Professional Development Plan²⁸ for each 5-year renewal cycle. A minimum of 150 professional development points must be earned during each 5-year cycle. The points can be earned in various ways. Generally, one point is the equivalent of 1 hour of intensive coursework.

Examinations and Assessments

National or Regional Examinations

The Massachusetts Education Reform Act (1993)²⁹ was established to provide an education system that would give all children the opportunity to reach their full potential and to be contributors in an increasingly global and knowledge-based society. Education reform raised the stakes for all Massachusetts public schools by setting new, higher expectations for student performance.

The No Child Left Behind (NCLB) Act³⁰ requires schools to administer tests in English language arts and mathematics annually to students in grades 3–8 and 10. In addition, districts are required to administer tests in science and technology/engineering at three grade levels (elementary, middle, and high school). The main goal of the NCLB is to help all students reach proficiency in English language arts and mathematics by the year 2014.

Massachusetts administers the Massachusetts Comprehensive Assessment System (MCAS)³¹ to all students in grades 3–8 and high school annually in the following content areas.

- *English language arts*: grades 3–8 and 10
- *Mathematics*: grades 3–8 and 10
- *Science and technology/engineering*: grades 5, 8, and 9/10
- *History and social science*: grades 5, 7, and 10/11 (pilot in 2007).

As required by the Massachusetts Education Reform Law,³² in addition to meeting all local requirements, students must pass the grade 10 tests in English language arts and mathematics as one part of the competency determination for a high school diploma. In addition, beginning with the class of 2010, all students must pass an assessment in one of the end-of-course tests in science and technology/engineering, biology, chemistry, introductory physics, or technology/engineering.³³

Massachusetts also participates in the National Assessment of Educational Progress (NAEP), known as The Nation's Report Card.³⁴ NAEP is a national assessment that assesses representative samples of students in grades 4, 8, and 12 in the subject areas of reading, mathematics, science, and writing.

In addition, Massachusetts also participates in the development and field testing of the American Diploma Project algebra II assessment,³⁵ which is designed to assist high schools by providing student-level diagnostic results and a valid indication of readiness for college-level coursework in mathematics.

Monitoring Individual Student Progress

The monitoring of individual student progress is performed at the local level.

Grade Promotion and Retention Policies

Each school district is responsible for establishing policies on grade promotion and retention.

References

- 1 Selected Massachusetts General Laws 2007 for School Committees and Personnel, Chapter 69, Section 1B
- 2 Selected Massachusetts General Laws 2007 for School Committees and School Personnel, Chapter 69, Section 1D and Section 1E
- 3 Individuals with Disabilities Education Act (IDEA) of 2004: <http://www.wrightslaw.com/law/idea/section1412.pdf>
- 4 What's new in school and district profiles: <http://profiles.doe.mass.edu/>
- 5 Education laws and regulations: <http://www.doe.mass.edu/lawsregs/603cmr8.html?section=all>
- 6 The General Laws of Massachusetts, Part I. Administration of the government, Title XII. Education, Chapter 76. School Attendance, Section 1. Requirements and exceptions: <http://www.mass.gov/legis/laws/mgl/76-1.htm>

References (Continued)

- 7 Selected Massachusetts General Laws 2007 for School Committees and School Personnel
- 8 Selected Massachusetts General Laws for School Committees and School Personnel, Chapter 15D
- 9 Selected Massachusetts General Laws 2007 for School Committees and School Personnel, Chapter 71, Section 89
- 10 Selected Massachusetts General Laws 2007 for School Committees and School Personnel, Chapter 71A
- 11 What's new in school and district profiles: <http://profiles.doe.mass.edu/>
- 12 Ibid.
- 13 Office for Mathematics, Science and Technology/Engineering, Massachusetts Department of Education
- 14 Title II B, the Massachusetts Mathematics and Science Partnership Program, is part of the No Child Left Behind Act of 2001.
- 15 Title II A, Teacher Quality Grant Programs, is part of the No Child Left Behind Act of 2001.
- 16 Massachusetts Curriculum Frameworks in Mathematics and Science and Technology/Engineering: www.doe.mass.edu/frameworks/current.html
- 17 Ibid.
- 18 Ibid.
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- 20 Student learning time: <http://www.doe.mass.edu/lawsregs/603cmr27.html?printscreen=yes§ion=04>
- 21 Extended Learning Time Planning Grant: <http://www.doe.mass.edu/sdi/081205.html>
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- 25 Massachusetts Department of Education. (2007, spring). *Principal's administration manual, spring 2007*. Retrieved May 18, 2008, from <http://www.doemass.org/mcas/2007/admin/manual/pam.pdf>
- 26 603 CMR 7.00, Regulations for Educator Licensure and Preparation Program Approval: www.doe.mass.edu/lawsregs/603cmr7.html
- 27 Ibid.
- 28 Professional development: <http://www.doe.mass.edu/pd/>
- 29 Education reform: <http://www.doe.mass.edu/edreform/>
- 30 The White House, forward by President George W. Bush: <http://www.whitehouse.gov/news/reports/no-child-left-behind.html>
- 31 Massachusetts Comprehensive Assessment System: <http://www.doe.mass.edu/mcas/>
- 32 Selected Massachusetts General Laws 2007 for School Committees and School Personnel, Chapter 69, Section 1D
- 33 2008 participation requirements and information about additional testing opportunities for the MCAS high school science and technology/engineering (STE) tests: <http://www.doe.mass.edu/news/news.asp?id=3853>
- 34 National Assessment of Education Progress: NAEP Resources: <http://www.doe.mass.edu/mcas/naep/resources.html>
- 35 Massachusetts is one of nine states to offer a voluntary algebra II examination: <http://www.doe.mass.edu/news/news.asp?id=3364>



Minnesota, United States

Christine Dufour

Minnesota Department of Education

Introduction

Overview of Education System

Minnesota has a long tradition of providing one of the best education systems in the United States of America, with its students scoring near the top nationally in academic achievement tests. However, if Minnesota is going to prepare its students—its citizens—to seize the opportunities of the 21st century, it cannot rest on its past success. With that reality in mind, Minnesota is taking its education system from nation-leading to world-competing. To gain a better sense of how Minnesota students perform compared to students internationally, the state is participating in TIMSS 2007.

Minnesota has a decentralized education system with 339 school districts, as well as 132 charter schools.¹ Minnesota's tradition of local control allows school districts and charter schools to meet the needs of their learners. The schooling choices include public schools, charter schools, online schools, and private schools. Charter schools are independent public schools. The first charter school in the United States opened in Minnesota in 1992. Other options include online learning through an approved provider, homeschooling, or private schools (of which there are 495 funded independently through tuition).

The Minnesota Department of Education (MDE) oversees educational policy, enforces educational laws, oversees state financing, implements state assessments, and provides educational leadership. The MDE requires that districts implement academic standards in mathematics, science, the arts, social studies, and language arts for all students, kindergarten through grade 12. There also are instructional requirements for health and physical education, career and technical education, and world languages.

Districts and schools have authority over curriculum, instructional delivery, and the integration of required standards into coursework. Districts evaluate student work and grant credit based on that work, including transfer credits from other schools.

Minnesota requires all children, ages 7–16, to attend school. School districts often separate students by grade level: elementary grades (K–4), intermediate or middle grades (5–8), and high school grades (9–12). Alternative Learning Centers offer middle

or high school students an educational alternative to receive individualized instruction. Early childhood education is offered for children from birth to age 5.

Funding for Minnesota's public schools comes from state aid (68%), federal aid (6%), local property taxes (18%), and local nontax revenues (8%). A majority of state and local funding is allocated to districts and charter schools through the general education program, which provides all schools with an equal amount of unrestricted funding per weighted pupil unit (\$5,074 in 2008). Districts receive additional funding relating to student characteristics (e.g., concentration of poverty and English language learners) and district characteristics (e.g., low population density and low enrollment). Also, districts and charter schools receive categorical funding for certain high-cost programs such as special education, and community education programs such as Early Childhood Family Education and Adult Basic Education. Districts are permitted to make property tax levies for purposes specified in state law and may enact additional operating or debt service levies with voter approval.

Language and Population

English is the language of instruction. Minnesota educates over 63,000 English language learners. These students, whose native language is not English, speak over 80 different native languages. Minnesota's K–12 population consists of 639,695 white, 74,987 black, 48,865 Asian or Pacific Islander, 47,390 Hispanic, and 18,247 Native American students.²

Emphasis on Mathematics and Science

Minnesota expanded Advanced Placement and the International Baccalaureate programs and expanded access to rigorous assessments to earn college credit while in high school.³ Promotion of dual enrollment—giving students multiple pathways to earn college credit while in high school—is a top priority of the department and is being accomplished through outreach and partnerships with high schools, postsecondary institutions, and businesses. Advanced Placement participation increased 20 percent, and International Baccalaureate programs increased by 12 percent. Also, Minnesota revised its mathematics standards to align with college, and its work readiness skills to better prepare students for a hypercompetitive global economy. In addition, Minnesota passed a requirement that students take algebra I by eighth grade and algebra II and chemistry or physics to graduate from high school, beginning with students expected to graduate in 2015.

Minnesota is focusing on increased academic rigor and accountability, placing a greater focus on science, technology, engineering, and mathematics (STEM) and improved teacher effectiveness. For 2008–2009, STEM grants will provide \$3 million each year to create partnerships that improve college readiness and encourage STEM career paths. The Minnesota Department of Education is striving to increase the number of students taking STEM courses at the middle and high school levels. Scholarships were provided by the federal government for students pursuing these disciplines at postsecondary institutions.

The 2006 STEM Summit reached 800 students at the Science Museum of Minnesota to see postsecondary, business, and real-world STEM applications. In 2008, STEM Summits expanded to eight locations throughout Minnesota reaching as many as 800 students per event. The MDE also has formed a partnership with Parametric Technology Corporation, a company that is providing free access to their mechanical engineering and design software to Minnesota teachers and students.

Minnesota will be creating regional Mathematics and Science Teacher Academies that will provide professional development for mathematics and science teachers and enhancements of statewide STEM initiatives.⁴

Overarching Policies Related to Education and the Curriculum for Mathematics and Science
Minnesota is working to prepare students to take advantage of the 21st century opportunities. Economic forecasts project a 20 to 33 percent increase in scientific and technical occupations in Minnesota in 10 years. New job growth in Minnesota's professional and high-tech industries will demand an extra 10,500 college graduates per year.⁵ Stimulating interest in these 21st century opportunities is a major focus of the Minnesota Department of Education's campaign to encourage students to take more STEM courses and explore STEM careers.

The Mathematics Curriculum in Primary and Lower Secondary Grades

Summary of National Curriculum Guides for Mathematics Through Eighth Grade

The MDE defines common academic standards as a measure of what all students must know and be able to do. The Minnesota K–12 academic standards in mathematics articulate the concepts of reasoning; number sense, computation, and operations; patterns, functions, and algebra; data analysis, statistics, and probability; and spatial sense, geometry, and measurement.⁶ The following are the mathematics topics and skills taught in **grade 4**.

- *Number and operation:* compare and represent whole numbers up to 100,000, with an emphasis on place value; demonstrate mastery of multiplication and division basic facts, multiply multidigit numbers, and solve real-world and mathematical problems using arithmetic; and represent and compare fractions and decimals in real-world and mathematical situations and use place value to understand how decimals represent quantities.
- *Algebra:* use input-output rules, tables, and charts to represent patterns and relationships and to solve real-world and mathematical problems; and use number sentences involving multiplication, division, and unknowns to represent and solve real-world and mathematical problems and create real-world situations corresponding to number sentences.
- *Geometry and measurement:* name, describe, classify, and sketch polygons; understand angle and area as measurable attributes of real-world and mathematical objects and use various tools to measure angles and areas; and use translations, reflections, and rotations to establish congruency and understand symmetries.

- *Data analysis*: collect, organize, display, and interpret data, including data collected over a period of time and data represented by fractions and decimals.

The following are the mathematics topics and skills taught in **grade 8**.

- *Number and operation*: read, write, compare, classify, and represent real numbers and use them to solve problems in various contexts.
- *Algebra*: understand the concept of function in real-world and mathematical situations and distinguish between linear and nonlinear functions; recognize linear functions in real-world and mathematical situations; represent linear functions and other functions with tables, verbal descriptions, symbols, and graphs; solve problems involving these functions and explain results in the original context; generate equivalent numerical and algebraic expressions and use algebraic properties to evaluate expressions; and represent real-world and mathematical situations using equations and inequalities involving linear expressions, solve equations and inequalities symbolically and graphically, and interpret solutions in the original context.
- *Geometry and measurement*: solve problems involving right triangles using the Pythagorean theorem and its converse and solve problems involving parallel and perpendicular lines on a coordinate system.
- *Data analysis and probability*: interpret data using scatterplots and approximate lines of best fit and use lines of best fit to draw conclusions.

The Science Curriculum in Primary and Lower Secondary Grades

Summary of National Curriculum Guides for Science Through Eighth Grade

The Minnesota K–12 academic standards for science are categorized into four areas: history and nature of science, earth and space science, physical science, and life science.⁷

The following are the science topics and skills students will explore through **grade 5**.

- **History and nature of science.** Related to *scientific inquiry*, the student will raise questions about the natural world, make careful observations, and seek answers. Related to *scientific world view*, the student will understand that science is a human endeavor practiced throughout the world, understand the use of science as a tool to examine the natural world, and understand how science is used to investigate interactions between people and the natural world.
- **Earth and space science.** Related to the *water cycle, weather, and climate*, the student will observe weather changes, investigate weather cycles and conditions, and recognize that water on Earth cycles and exists in many forms. Related to *Earth's structure and processes*, the student will recognize basic Earth materials and investigate the impact humans have on the environment. Related to the *universe*, the student will recognize the changes that occur in the sky in a 24-hour day, understand the characteristics and relationships of objects in the solar system, and identify the patterns and movements of celestial objects.

- **Physical science.** Related to the *structure of matter*, the student will understand that objects have physical properties and can be sorted and classified based on their properties and know that heating and cooling may cause changes to the properties of a substance. Related to the *forces of nature*, the student will understand that forces can act at a distance and that a relationship exists between electricity and magnetism. Related to *motion*, the student will know that objects move in various ways. Related to *energy transformation*, the student will explore the characteristics and properties of sound and light and understand basic electricity and its application in everyday life.
- **Life science.** Related to *diversity of organisms*, the student will understand that there are living and nonliving things, recognize that plants and animals have life cycles and different structures that serve various functions, and know that living things can be sorted into groups in many ways according to their varied characteristics, structures, and behaviors. Related to the *human organism*, the student will understand that people have five senses that can be used to learn about the environment, know that the human body is made up of parts, learn that some diseases are caused by germs, recognize that people have basic needs, and know the structures that serve various functions in the human body, including protection from disease. Related to *heredity*, the student will understand that there is variation among individuals of one kind within a population and that many characteristics of an organism are inherited from its parents, but other characteristics result from an individual's interactions with the environment. Related to *flow of matter and energy*, the student will understand that organisms have basic needs and investigate feeding relationships among organisms. Related to the *interdependence of life*, the student will understand that organisms live in different environments and that an organism's patterns of behavior are related to the nature of its environment. The student will understand that *biological populations change over time*. Related to *cells*, the student will know that all organisms are composed of cells, which are the fundamental units of life.

The following are the science topics and skills students will explore in **grades 6–8**.

- **History and nature of science.** Related to *scientific inquiry*, the student will understand the process of scientific investigations, design and conduct scientific investigations, understand that scientific inquiry is used by scientists to investigate the natural world in systematic ways, and use multiple skills to design and conduct scientific investigations. Related to *scientific world view*, the student will understand that communication is essential to science and that science is a way of knowing about the world that is characterized by empirical criteria, logical argument, and skeptical review. Related to *scientific enterprise*, the student will recognize that science and technology involve different kinds of work and engage men and women of all backgrounds and know that science and technology are human efforts that both influence and are influenced by society and civilizations and cultures worldwide. Related to *historic perspectives*, the student will understand how scientific discovery, culture, societal norms, and technology have

influenced one another in different time periods and understand how scientific discovery, culture, societal norms, and technology have influenced one another in different time periods.

- **Earth and space science.** Related to *the water cycle, weather, and climate*, the student will investigate how the atmosphere interacts with the Earth system. Related to *Earth's structure and processes*, the student will explore the structures and functions of Earth systems; identify Earth's composition, structure, and processes; and investigate the impact humans have on the environment. Related to *the universe*, the student will compare objects in the solar system and explain their interactions with the Earth and describe the composition and structure of the universe.
- **Physical science.** Related to the *structure of matter*, the student will understand that matter is made of small particles and this explains the properties of matter. Related to the *forces of nature*, the student will understand that a variety of forces govern the structure and motion of objects in the universe. Related to *motion*, the student will understand that changes in speed or direction of motion are caused by forces and be able to describe the motion of objects. Related to *energy transformation*, the student will understand that energy exists in many forms and can be transferred in many ways. Related to *chemical reactions*, the student will differentiate between chemical and physical changes.
- **Life science.** Related to the *diversity of organisms*, the student will understand that living systems, at every level of organization, demonstrate the complementary nature of structure and function. Related to the *human organism*, the student will understand human body systems and their relationship to disease. Related to *heredity*, the student will understand that hereditary information is contained in genes that are inherited through both sexual and asexual reproduction. Related to the *flow of matter and energy*, the student will know that matter and energy flow into, out of, and within a biological system and understand how the flow of energy and the recycling of matter contribute to a stable ecosystem. Related to the *interdependence of life*, the student will understand that within ecosystems, complex interactions exist between organisms and the physical environment. Related to *biological populations change over time*, the student will know that biological populations change over time and understand how biological evolution provides a scientific explanation for the fossil record of ancient life forms, as well as for the striking similarities observed among the diverse species of living organisms. Related to *cells*, the student will understand that all organisms are composed of cells that carry on the many functions needed to sustain life.

Instruction for Mathematics and Science in Primary and Lower Secondary Grades

Instructional Time

Mathematical and scientific concepts are introduced as early as kindergarten and continue to build through elementary school, middle school, and high school. The curriculum and class schedules are determined locally by schools and school districts. The Minnesota Department of Education provides academic standards that guide districts in developing their programs.

Instructional Materials, Equipment, and Laboratories

Instructional materials are used to enrich and explain the curriculum. Each school district and school determines the curriculum, materials, and equipment necessary for their educational program.

Use of Technology

Each school and school district determines their technology needs locally. The Minnesota Department of Education provides grants through a federal program to enhance technology education at the local level.

The Enhancing Education Through Technology program is a federal program initiative that is part of the No Child Left Behind Act (NCLB). This program provides competitive grant funding to school districts to support the integration of technology with instruction to increase student achievement and provide sustained professional development for Minnesota teachers in the effective use of technology.

Teachers and Teacher Education

Education and Training for Fourth and Eighth Grade Mathematics and Science Teachers

In the 2006–2007 school year, there were 52,796 teachers in Minnesota with an average of 14 years of teaching experience in Minnesota public schools.⁸ The Minnesota teacher licensure and NCLB “highly qualified” verification are separate requirements.

- State law requires that all Minnesota teachers be licensed or hold permission through the Board of Teaching to teach in a public or charter school.
- The NCLB highly qualified teacher verification addresses content knowledge in core academic subjects, which include English, language arts or reading, mathematics, sciences, civics and government, history, geography, economics, world languages, and the arts.

There are several pathways to becoming a teacher, including the traditional 4-year degree with a student teaching experience and the teacher licensure application process. Also, teachers can pursue a graduate teaching degree with a 4-year degree in another field. An online degree also is available.

A teacher candidate must meet all of the Board of Teaching’s content and pedagogical standards that are set forth in Minnesota Board of Teaching rules. There is flexibility in

the delivery of these standards. As a result, the institutions that prepare teachers may have differing program requirements.

All teacher candidates must complete a minimum of 10 weeks of student teaching. Additionally, each licensure program must incorporate early and ongoing field experiences into the academic program prior to the student teaching experience.

A 2006 survey of Minnesota superintendents found that 57 percent perceived teacher shortages in physics, and 55 percent perceived teacher shortages in chemistry.⁹ In order to address the teacher shortage in the mathematics and science fields, especially in the rural areas, a science licensure rule was updated to allow science teachers to obtain another license in another area of science. Beginning in October 2007, a Minnesota teacher licensed in chemistry, physics, life science, or earth and space science (grades 9–12 or grades 7–12), who has taught science for at least 3 years, may take the content knowledge test in another area of science licensure (grades 9–12 only). If the teacher passes the test, he or she is eligible to apply for a teaching license in that licensure field.

Teacher Professional Development in Mathematics, Science, and Technology

The Minnesota Department of Education began hosting Mathematics and Science Teacher Academies in the spring of 2008. These academies serve as an infrastructure focused on the improvement of mathematics and science instruction and learning. The Mathematics and Science Teacher Academies will provide professional development and technical assistance to assist teachers in the following areas.

- Learning effective teaching approaches to implementing Minnesota standards
- Mastering multiple approaches for differentiating instruction and engaging students
- Improving skills for diagnosing student learning needs using an assessment of student performance.

There will be 10 regional centers in Minnesota referred to collectively as the Mathematics and Science Teacher Academy.

Examinations and Assessments

National or Regional Examinations

The Minnesota Comprehensive Assessments—Series II are the state tests that help districts measure student progress toward Minnesota's academic standards and meet the requirements of the No Child Left Behind Act.

Reading and mathematics tests are given in grades 3–8, 10 (reading only), and 11 (mathematics only). In spring 2008, science tests also will be given in grades 5 and 8 and once in high school, depending on when students complete their life sciences curriculum.

- The Minnesota Test of Academic Skills (MTAS) is Minnesota's alternate assessment based on alternate achievement standards. The MTAS is part of the

statewide assessment program and measures the extent to which students with significant cognitive disabilities are making progress in the general curriculum.

- The Graduation-Required Assessments for Diploma (GRAD) are state tests that fulfill Minnesota's high school graduation requirement for students graduating after 2010. These tests measure student performance on writing, reading, and mathematics for success in the 21st century. There also are retest opportunities.
- The Basic Skills Tests (BSTs) are reading, mathematics, and writing tests that students entering grade 8 in the 2004–2005 year or earlier must pass to receive a diploma. The reading and mathematics tests were first administered to these students in grade 8 and the writing test in grade 10. Students entering grade 8 in the 2005–2006 year or later do not take the BST but will take the Graduation-Required Assessments for Diploma (GRAD) component of the Minnesota Comprehensive Assessments—Series II in written composition in grade 9, reading in grade 10, and mathematics in grade 11. They must pass each test to graduate.
- The Test of Emerging Academic English (TEAE) is a reading and writing language proficiency test for English language learners in grades 3–12. It assesses progress in acquiring academic English. For K–12 learners, reading and writing is assessed with a teacher observation rating.
- The Minnesota Student Oral Language Observation Matrix (MN SOLOM) is a teacher observation matrix that assesses the listening and speaking skills of K–12 English language learners.
- The Mathematics Test for English Language Learners (MTELL) is a computer-delivered mathematics test in grades 3–8 and 11 with simplified English that reduces the confounding effects of language on mathematics performance. Students may listen to test items or read them. The MTELL assesses the same grade level standards as the Minnesota Comprehensive Assessments—Series II.
- The National Assessment of Educational Progress (NAEP) consists of tests in mathematics and reading, administered to students in grades 4 and 8 every other year. NAEP also includes special assessments and studies as part of an ongoing program. These include assessments in subjects other than mathematics and reading that are conducted during the even-numbered off years. In 2006, students were assessed at grades 4, 8, and 12 in U.S. history and civics. Grade 12 students also were tested in economics. The long-term trend study (also part of NAEP) tests students ages 9, 13, and 17 in reading and mathematics every 4 years to track performance of a national sample of students over an extended period of time.
- The Educational Planning and Assessment System® (EPAS) includes several tests developed by the American College Testing program (ACT) to assess student preparation for postsecondary education. Minnesota pays for the standard test reports when public school districts give the EXPLORE® to eighth graders and/or PLAN® to tenth graders in the 2007–2008 and 2008–2009 school years.

Monitoring Individual Student Progress

Individual student progress, such as grades, is determined at the local level.

Grade Promotion and Retention Policies

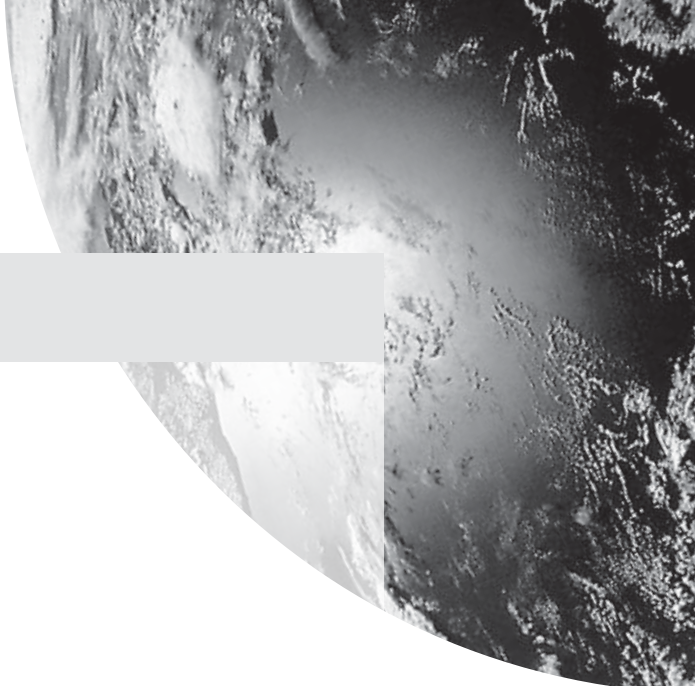
Grade promotion and retention policies are made at the district and school level. State graduation requirements for students include 21.5 course credits of which seven are elective credits. Students must also meet local requirements. Also, students must pass Graduation-Required Assessments for Diploma in written composition in grade 9, Minnesota Comprehensive Assessments—Series II or Graduation-Required Assessments for Diploma in reading in grade 10, and the Minnesota Comprehensive Assessments—Series II or Graduation-Required Assessments for Diploma in mathematics in grade 11 beginning in 2009.

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Ontario, Canada

Ontario Ministry of Education

Introduction

Overview of Education System

In Ontario, the Ministry of Education oversees the system of publicly funded elementary and secondary education. The ministry is responsible for curriculum and assessment policy, diploma requirements, and programs and funding, while implementation is the responsibility of school boards and schools.

Ontario has 60 English-language and 12 French-language school boards and 32 school authorities that serve small and remote communities. In the publicly funded education system, approximately 70 percent of students attend public schools and 30 percent attend separate (Roman Catholic) schools.¹ Approximately 4.25 percent of Ontario's students are enrolled in French-language boards.²

School boards offer junior and senior kindergarten (ages 4 and 5). Attendance at kindergarten is voluntary. Compulsory education begins at age 6 in grade 1. Elementary education covers grades 1–8 and secondary education, grades 9–12. Students are required to participate in learning until age 18 or graduation.

Ontario students' scores on TIMSS mathematics and science assessments in both grades 4 and 8 improved between 1995 and 2003. Key changes that occurred over this period of time included the introduction of a new curriculum with high standards, grade-by-grade framework and specific learning expectations, destination-related secondary school course types, criterion-referenced classroom and provincial assessments, and standardized provincial report cards.

Language and Population

The languages of instruction are English and French. Approximately 70 percent of Ontarians have English as their mother tongue, 4 percent have French, and 26 percent have a first language other than English or French.³ More than one in five elementary/secondary students have a first language other than English.

Second-language Instruction

The government provides policy direction, programs, and funding to school boards for students to acquire proficiency in the official languages of instruction. English-language learners are encouraged to build on their prior knowledge and use their first language to assist in developing English-language proficiency.

Emphasis on Mathematics and Science

The Ministry of Education commissioned several reports on improving mathematics instruction. *The Early Math Strategy: The Report of the Expert Panel on Early Math in Ontario, 2003*⁴ provides K–3 teachers with principles of effective mathematics instruction and assessment to support students' learning. Similarly, *Teaching and Learning Mathematics, The Report of the Expert Panel on Mathematics in Grades 4 to 6 in Ontario 2004*⁵ supports instruction in grades 4–6. Online numeracy resources, such as video modules and instructional guides, have been developed to support teachers from kindergarten through grade 6.^{6,7,8,9} In 2005, the ministry released *Education for All, the Report of the Expert Panel on Literacy and Numeracy Instruction for Students with Special Education Needs, K–6*.¹⁰

The ministry established the Literacy and Numeracy Secretariat to provide expert coordination and direct support in the field to improve literacy and numeracy skills from kindergarten to grade 6 and to close gaps in student achievement. The secretariat works with school boards and schools to improve school and classroom practices and build system capacity. The secretariat also provides ongoing professional learning, conducts research, and shares best practices.¹¹

The Mathematics Curriculum in Primary and Lower Secondary Grades

Summary of Curriculum Guides for Mathematics Through Eighth Grade

The elementary mathematics curriculum for Ontario¹² is based on the belief that all students can learn mathematics and deserve the opportunity to do so. Students acquire a solid conceptual foundation through learning about the interrelated mathematics concepts that form a framework for learning mathematics in a coherent way. The fundamentals of important concepts, processes, skills, and attitudes are introduced in the primary grades and are elaborated on through the junior and intermediate grades. The mathematics curriculum places emphasis on the mathematical processes of problem solving, reasoning and proving, reflecting, selecting tools and computational strategies, connecting, representing, and communicating.

Problem solving is central to learning mathematics and is interconnected with the other mathematical processes. By learning to solve problems and learning through problem solving, students are provided with ongoing learning experiences from which they can connect mathematical ideas and develop conceptual understanding. Problem solving helps students use the knowledge they bring to school and connects mathematics with situations outside the classroom. It also helps students develop mathematical understanding and gives meaning to skills and concepts in all strands. By problem solving, students learn to reason, communicate ideas, make connections, apply knowledge and

skills, and promote the collaborative sharing of ideas, strategies, and talking about mathematics.

The mathematics curriculum for grades 1 to 8 is organized into five strands: number sense and numeration, measurement, geometry and spatial sense, patterning and algebra, and data management and probability.

At **grade 4**, the *number sense and numeration* strand focuses on working with whole numbers, decimals, and simple fractions; understanding magnitude; solving problems; and using proportional reasoning. The *measurement* unit involves using strategies to estimate, measure, and record length, perimeter, area, mass, and volume and determining the relationships among units and measurable attributes. *Geometry and spatial sense* involves geometric properties of quadrilaterals and three-dimensional figures and comparisons of various angles to benchmarks, construction of three-dimensional figures, and the identification and description of the location of an object. The *patterning and algebra* strand involves numeric and geometric patterns, predictions related to patterns, repeating patterns, and understanding equality between pairs of numeric expressions. *Data management and probability* involves collection and display of discrete primary data; interpretation of primary and secondary data; and prediction related to a simple probability experiment, carrying out an experiment, and comparing the prediction to the results.

At **grade 8**, the *number sense and numeration* strand focuses on using equivalent representations for numbers including positive exponents; solving problems using whole numbers, decimal numbers, fractions, and integers; and using proportional reasoning in meaningful contexts to solve problems. The *measurement* unit deals with applications of volume and capacity and relationships among units and measurable attributes, including the area of a circle and volume of a cylinder. *Geometry and spatial sense* includes an understanding of the geometric properties of quadrilaterals and circles; developing relationships and solving problems involving lines, triangles, and polyhedra; and using the coordinate plane to represent transformations. *Patterning and algebra* focus on using graphs, algebraic expressions, and equations to represent linear growth patterns; modeling linear relationships, both graphically and algebraically; and solving and verifying algebraic equations. *Data management and probability* focuses on the collection and organization of data and exploring data relationships and the use of probability models to make predictions about real-life events.

The Science Curriculum in Primary and Lower Secondary Grades

Summary of Curriculum Guides for Science Through Eighth Grade

The Ontario curriculum for grades 1–8 science and technology (1998)¹³ and the revised version (released in late 2007)¹⁴ are consistent with the goals of science education in Canada outlined in the Common Framework of Science Learning Outcomes, K–12.¹⁵ The learning outcomes are intended to develop scientific literacy in Canadian students.

In science and technology, students need to develop a thorough knowledge of basic concepts, develop broad-based skills and identify, analyze, and find solutions to problems.

Students learn, in age-appropriate ways, to consider both the knowledge and skills that will help them understand and consider critically the impact of developments in science and technology on modern society and the environment.

Through scientific investigation, students engage in activities that allow them to develop knowledge and understanding of scientific ideas in much the same way as scientists. Through technological investigation, students engage in exploration and experimentation and develop the ability to design solutions to problems, such as designing, making, and testing devices.

The curriculum is organized according to the following strands: life systems, matter and materials, energy and control, structures and mechanisms, and Earth and space systems.

At **grade 4**, in the *life systems* strand, students learn about all living things that have basic or unique needs met from the environment and about the responsibility of humans to protect plants and animals and their habitats. In *matter and materials*, students learn about materials in connection with light and sound, investigate materials, and apply their learning through selecting material and designing objects. *Energy and control* focuses on energy from the sun and in other forms, including light and sound energy, and the responsible use of energy. The *structures and mechanisms* strand focuses on structures that have both form and function and are affected by forces acting on them (e.g., simple machines and mechanisms that make life easier and/or more enjoyable for humans and the use of objects and materials that have a direct effect on the environment). In *Earth and space systems*, students learn that our actions affect the quality of air, soil, and water and their ability to sustain life and that human use of rocks and minerals affects the environment in various ways.

At **grade 8**, in *life systems*, students examine cells that are the basis of life and choices that humans make that affect organ systems and overall health. In the *matter and materials* strand, students learn about properties and the buoyant force of fluids, investigate these and other properties, design systems to solve specific problems, and relate knowledge of the properties of fluids to the natural world and technological devices. The *energy and control* unit involves changes of states of matter, the particle theory of matter, and characteristics of matter that allow us to make informed choices about how we use it, the essential nature of fluids to life, fluids in systems, and properties of fluids that determine how they can be used. *Structures and mechanisms* look at the predictable interaction between structures and forces and also systems that are designed to accomplish tasks and optimize human and natural resources. In *Earth and space systems*, the focus is on water, which is crucial to life on Earth and an important resource that needs to be managed sustainably.

In late 2007, the Ministry of Education released the Ontario Curriculum, grades 1–8 science and technology, which was revised for implementation in the fall of 2008. In the revised curriculum, key goals and fundamental concepts and ideas provide a framework for teaching overall and specific expectations. The revised curriculum has three goals: to relate science and technology to society and the environment; to develop the skills,

strategies, and habits of mind required for scientific investigation and technological problem solving; and to understand the basic concepts of science and technology. The three goals and their interrelationship within the curriculum expectations reinforce the notion that learning in science and technology cannot be viewed as merely the learning of facts. Rather, science and technology is a subject in which students learn, in age-appropriate ways, to consider both the knowledge and skills that will help them understand and consider critically the impact of developments in science and technology on modern society and the environment. The revised science and technology curriculum expectations are organized into four strands: understanding life systems, understanding structures and mechanisms, understanding matter and energy, and understanding Earth and space systems.

Instruction for Mathematics and Science in Primary and Lower Secondary Grades

Instructional Time

At the elementary level, students receive 25 hours per week of instructional time. Decisions regarding the amount of time spent on any particular area of the elementary curriculum (with the exception of French as a second language and daily physical activity) are made at the local level. In the report *Leading Math Success*,¹⁶ an expert panel in Ontario recommended a minimum of an hour per day of focused mathematics instruction in grades 7 and 8.

At the secondary level, grades 9–12, students earn credits through successful completion of courses that are a minimum of 110 hours in length. Students working towards a secondary school diploma must complete three compulsory credits in mathematics, with at least one credit in grade 11 or 12, and two in science.

Instructional Materials, Equipment, and Laboratories

The Ministry of Education in Ontario provides a list of evaluated and approved textbooks for use by students in Ontario classrooms. Textbooks approved by the ministry must support at least 85 percent of the curriculum expectations for the subject area.

Grade Specialist Teachers for Mathematics and Science Are Introduced

Teachers who are qualified to teach at the junior (grades 4–6) and intermediate (grades 7–10) levels are required to have one teachable subject. In elementary grades, there are no other specific requirements for a specialist teacher. Ontario has recently invested in new elementary specialist teachers for the core subject areas of English or French, mathematics, and science and technology. Teachers in elementary schools may take an additional three-part specialist qualification program if they wish to deepen their expertise in a subject area.

Use of Technology

Information and communication technology (ICT) provide a range of tools that can significantly extend and enrich teachers' instructional strategies and support students' learning in mathematics and in science and technology. Students are encouraged in the appropriate use of ICT to support and communicate their learning.

Teachers and Teacher Education

Education and Training for Fourth and Eighth Grade Mathematics and Science Teachers

To teach in the publicly funded school system, a teacher must be certified by the Ontario College of Teachers. Certification requirements include a minimum of a 3-year postsecondary degree from an acceptable postsecondary institution and a 1-year teacher education program, including at least 8 weeks of practice teaching. Teachers receive qualifications in two consecutive divisions of the elementary or secondary school system (primary or junior, junior or intermediate with one subject, or intermediate or senior with two subjects). Teacher qualifications are regulated by the college through a formal accreditation process.

Teacher Professional Development in Mathematics, Science, and Technology

In Ontario, responsibility for regulating teachers' professional development is shared between the Ministry of Education and the college. The college sets professional standards for teachers and provides for teachers' ongoing learning through its Professional Learning Framework.¹⁷ Boards of education and teachers' federations are key partners in developing, delivering, and monitoring professional development for teachers. The ministry's Literacy and Numeracy Secretariat offers elementary school teachers' professional learning opportunities, such as regional mathematics implementation days and summer literacy and numeracy training.

Examinations and Assessments

In 1996, Ontario established the Education Quality and Accountability Office to develop and administer assessments throughout the province based on the Ontario curriculum. Currently, assessments are administered annually in English or French to all students in grades 3 and 6 (reading, writing, and mathematics), grade 9 (mathematics), and grade 10 (the Ontario Secondary School Literacy Test). Individual student's results are reported for all assessments, but the results do not affect student's grades or promotion in grades 3, 6, and 9. Grade 9 teachers have the option of scoring their mathematics tests and counting the results as a portion of the course grade. To obtain an Ontario secondary school diploma, all students must satisfy a graduation literacy requirement. Most students meet this requirement by passing the Ontario Secondary School Literacy Test. Students who are not successful on this test may retake it or meet the requirement by receiving a passing grade in the Ontario Secondary School Literacy Course.

The assessments at grades 3, 6, and 9 are based on Ontario curriculum expectations for specific courses and the literacy test is based on the reading and writing expectations across all courses up to the end of grade 9. All assessments contain multiple-choice and open-response questions, and all writing assessments include extended writing.

Other Tests

In Ontario, individual school boards or schools determine whether or not to use commercial standardized tests of mathematics achievement such as the Canadian Test of Basic Skills.

Monitoring Individual Student Progress

Classroom assessment and evaluation are based on the expectations in the provincial curriculum that include both overall expectations, which are the basis for evaluation, and specific expectations. All curriculum documents have achievement charts with four categories of knowledge and skills and four levels of achievement. The provincial standard or expected level of achievement is level 3, which is the level at which teachers and parents can be confident that students are well prepared for work in the next grade or the next course.

Grade Promotion and Retention Policies

In elementary schools, decisions on promotion and retention are made by the principal of the school in consultation with parents. In secondary schools, students receive credit for every course in which their grade is 50 percent or higher.

Suggested Readings

For more information in English and French, see the Ontario Ministry of Education's website at <http://www.edu.gov.on.ca> and the Education Quality and Accountability Office's website at <http://www.eqao.com>.

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Introduction

Overview of Education System

In Québec, the education system offers a variety of programs and services from preschool to university. The role of the *Ministère de l'Éducation, du Loisir et du Sport* (Ministry of Education, Recreation, and Sports) depends on the level of education concerned. In preschool, elementary, secondary, and college education, the ministry establishes the programs and defines the objectives and often the content or the standards. With regard to labor relations, the ministry negotiates and signs provincial collective agreements. With regard to funding, it defines a normative framework and provides most of the resources.

The Québec Education Program is based on the development of competencies. It includes cross-curricular competencies (i.e., those needed in all subject areas), broad areas of learning that deal with the major spheres of young people's lives, and subject-specific programs of study in various subject areas. The term "competency" is defined as follows in the Québec Education Program: "a set of behaviours based on the effective mobilization and use of a range of resources."¹ A program based on developing competencies focuses, among other things, on knowledge that can serve as tools for both action and thought development. In this context, the competency is complex and develops over time; it involves more than the mere addition or juxtaposition of elements, and students can continue increasing their mastery of a competency throughout their schooling, and indeed, beyond it.

The preschool and elementary education programs were implemented in Québec schools in September 2000. The Secondary Cycle One program was put into practice in September 2005. Application of the Secondary Cycle Two program began in September 2007 and is taking place over 3 years. The implementation of the Québec Education Program is a major undertaking on the part of the ministry. Among other things, it establishes initial teacher training and professional development programs,

develops instructional materials consistent with the competency-based approach, and makes use of a variety of resources in the schools.

The preschool, elementary, and secondary education system provides services from kindergarten to secondary V, including vocational training. Preschool education is for 5 year olds and is full time but not compulsory, although nearly all children are enrolled. Children with disabilities or those from disadvantaged areas also may be admitted to preschool education starting at age 4. Elementary education is divided into three learning cycles that are 2 years each. Elementary school attendance is compulsory. Secondary education consists of 5 years of studies divided into two cycles. Similar to elementary school, Secondary Cycle One includes common core education for all students and lasts 2 years. Secondary Cycle Two lasts 3 years. School is compulsory for students up to the age of 16, which normally corresponds to the fifth year of secondary school.

The public school system is administrated by 72 linguistic school boards, of which 60 are French, nine English, and three have a special status (two of these provide services mainly to aboriginal students). Elementary and secondary education also are provided by private institutions, some of which are partially funded by the ministry. Private educational institutions serve 5 percent of elementary students and 17 percent of secondary students. These institutions are subject to the same regulations as public institutions and must implement the official curriculum.

Language and Population

The official language and the language of instruction in Québec is French. Approximately 80 percent of the total population of Québec is French speaking. The English-speaking population, which accounts for about 9 percent of the total, has access to a full network of English educational institutions, from preschool to university. There are 11 aboriginal nations in Québec. Eight of them are under federal jurisdiction, while the other three are the responsibility of the ministry.

Second-language Instruction

Increased immigration has resulted in the arrival of large numbers of students whose first language is neither French nor English, especially in the greater Montréal area. While children are taught in their native language for the first 4 years of elementary school, schools offer francization services, which are intended to establish French as the primary language, and welcoming classes to meet these students' particular needs.

The Mathematics Curriculum in Primary and Lower Secondary Grades

Summary of National Curriculum Guides for Mathematics Through Eighth Grade

Mathematics is a compulsory subject in Québec throughout elementary and secondary schools.^{2,3} The mathematics programs contain only compulsory concepts and processes. These concepts are grouped together by cycle in the three cycles of elementary school and Secondary Cycle One, and by year for each of the 3 years of Secondary Cycle Two. Three options are available to Secondary IV and V students: cultural, social, and technical; technical and scientific; and science. Students who wish to pursue their studies in science

or certain technical training programs (college level, the 12th and 13th year of the studies) must successfully complete the appropriate option. Learning mathematics enables students to do the following.

- Use mathematical reasoning to formulate and validate conjectures
- Communicate in contexts in which the object of the message, the purpose of the communication and the target audience play a significant role
- Understand aspects of a problem with a view to finding a solution.

Thus, students develop skills in interpreting reality, predicting, generalizing, and making decisions in a changing world. By the end of Secondary Cycle One, Québec students who have successfully completed the mathematics program should have mastered the concepts in Exhibit 1.

Exhibit 1 Mathematics Concepts for Students in Secondary Cycle One

Arithmetic	
<p>Number Sense with Regard to Decimal and Fractional Notation and Operation Sense</p> <p>Reading, writing, various representations, patterns, and properties</p> <p>Fractional, decimal, and exponential (integral exponent) notation, percentage, and square root</p> <p>Properties of divisibility (by 2, 3, 4, 5, and 10)</p> <p>Rules of signs for numbers written in decimal notation</p> <p>Equality relation: meaning and properties and rules for transforming numerical equalities (balancing equalities)</p> <p>Inverse operations: addition and subtraction, multiplication and division, and square and square root</p> <p>Properties of operations</p> <ul style="list-style-type: none"> • Commutative and associative properties • Distributive property of multiplication over addition or subtraction and factoring out the common factor <p>Order of operations and the use of no more than two levels of parentheses in different contexts</p>	<p>Understanding Proportionality</p> <p>Ratio and rate</p> <ul style="list-style-type: none"> • Ratios and equivalent rates • Unit rate <p>Proportion</p> <ul style="list-style-type: none"> • Equality of ratios and rates • Ratio and proportionality coefficient <p>Direct or inverse variation</p>
Probability	Statistics
<p>Random Experiment</p> <p>Random experiment</p> <ul style="list-style-type: none"> • Random experiments involving one or more steps (with or without replacement and with or without order) • Outcome of a random experiment • Sample space <p>Event</p> <ul style="list-style-type: none"> • Certain, probable, and impossible events • Simple, complementary, compatible, incompatible, and dependent and independent events <p>Theoretical probability and experimental probability</p>	<p>Statistical Reports</p> <p>Population, sample</p> <ul style="list-style-type: none"> • Sample survey, poll, and census • Representative sample • Sampling methods: simple random and systematic • Sources of bias <p>Data</p> <ul style="list-style-type: none"> • Qualitative variable • Discrete or continuous quantitative variable <p>Table characteristics and frequencies</p> <p>Reading bar graphs, broken-line graphs, and circle graphs</p> <p>Arithmetic mean</p> <p>Range</p>

Exhibit 1 Mathematics Concepts for Students in Secondary Cycle One (Continued)

Geometry	Algebra
<p>Geometric Figures⁴ and Spatial Sense</p> <p>Plane figures</p> <ul style="list-style-type: none"> • Triangles, quadrilaterals, and regular convex polygons <p style="padding-left: 20px;">Main segments and lines: bisector, perpendicular bisector, median, and altitude</p> <ul style="list-style-type: none"> • Circle and sector: <p style="padding-left: 20px;">Radius, diameter, chord, and arc</p> <p style="padding-left: 20px;">Central angle</p> <ul style="list-style-type: none"> • Measurement: <p style="padding-left: 20px;">Degree: angle and arc</p> <p style="padding-left: 20px;">Length</p> <p style="padding-left: 20px;">Perimeter and circumference</p> <p style="padding-left: 20px;">Area, lateral area, and total area</p> <p style="padding-left: 20px;">Choice of unit of measure for lengths or areas</p> <p style="padding-left: 20px;">Relationships between SI⁵ units of length</p> <p style="padding-left: 20px;">Relationships between SI units of area</p> <p>Angles</p> <ul style="list-style-type: none"> • Complementary and supplementary • Formed by two intersecting lines: vertically opposite and adjacent • Formed by a transversal intersecting two other lines: alternate interior, alternate exterior, and corresponding <p>Solids</p> <ul style="list-style-type: none"> • Right prisms, right pyramids, and right cylinders • Possible nets of a solid • Decomposable solids <p>Congruent and similar figures</p>	<p>Understanding Algebraic Expressions</p> <p>Algebraic expression</p> <ul style="list-style-type: none"> • Variable • Coefficient • Degree • Terms and like terms <p>Equality, equation, and the unknown</p> <p>First-degree equation with one unknown expressed in the form $ax + b = cx + d$</p>

The Science Curriculum in Primary and Lower Secondary Grades

Summary of National Curriculum Guides for Science Through Eighth Grade

Science and technology is a compulsory subject in Québec from the Elementary Cycle Two through the second year of Secondary Cycle Two (Secondary IV).^{6,7} The science and technology programs for the third year of Secondary Cycle Two (Secondary V) are optional. Students who wish to pursue their studies in science or certain technical training programs (college level, 12th and 13th year of studies) must successfully complete Secondary V physics and/or Secondary V chemistry. Learning science and technology enables students to do the following.

- Seek answers or solutions to scientific or technological problems
- Make the most of their knowledge of science and technology
- Communicate in the languages used in science and technology.

By the end of Secondary Cycle One, Québec students who have successfully completed the science and technology programs should have mastered the concepts and skills in Exhibit 2.

Exhibit 2 Science and Technology Concepts for Students in Secondary Cycle One

Living World		
Diversity of Life Forms Habitat Ecological niche Species Population Physical and behavioral adaptation Differences and similarities among various species Taxonomy Transmission of hereditary traits from generation to generation through genes and chromosomes Use of techniques for designing and manufacturing environments	Survival of Species Asexual and sexual reproduction Reproductive mechanisms in plants and animals Birth control methods Contraception Methods of preventing the implantation of the zygote in the uterus Sexually transmitted and blood-borne diseases	Life-sustaining Processes Characteristics of living things Plant and animal cells Photosynthesis and respiration Cellular components visible under a microscope Inputs and outputs (energy, nutrients, and waste) Osmosis and diffusion
Material World		
Properties Characteristic properties of matter Concepts of mass, volume, and temperature Changes in the state of matter (solid, liquid, and gas) Acidity or alkalinity	Changes Physical and chemical changes Conservation of matter (conservation of the number of atoms) Mixtures Solutions Separation of mixtures	Organization Difference between an atom and a molecule Element Periodic table: a list of atoms
Earth and Space		
General Characteristics of the Earth Internal structure of the Earth Hydrosphere, lithosphere, and atmosphere Types of rocks (basic minerals) Types of soil Relief Atmospheric layers Water (distribution) Air (composition)	Geological and Geophysical Phenomena Tectonic plate Volcano Earthquake Orogenesis Erosion Natural energy sources Winds Water cycle Renewable and nonrenewable energy resources	Astronomical Phenomena Universal gravitation (qualitative study) Solar system Light (properties) Cycles of day and night Phases of the moon Eclipses Seasons Comets Aurora borealis Meteoroid impact
Technological World		
Engineering Specifications Design plan and technical drawing Manufacturing process sheet Raw material Material Equipment Drafting techniques Scales Manufacturing techniques	Technological Systems System (overall function, inputs, processes, outputs, and control) Components of a system Basic mechanical functions (links and guiding control) Energy transformations	Forces and Motion Bases on the Analysis of a Technical Object Types of motion Effects of a force Simple machines Mechanisms that bring about a change in motion

Instruction for Mathematics and Science in Primary and Lower Secondary Grades

Instructional Time

The basic school regulation provides for 7 hours a week of mathematics in Elementary Cycle One, and 5 hours in Cycles Two and Three. It also includes 150 hours of mathematics per year for the first 3 years of secondary school.

The basic school regulation does not indicate any set time for science and technology in Elementary Cycle One. Competencies related to science and technology must be taught in other subjects. In Elementary Cycles Two and Three, the basic school regulation prescribes an hour a week for science and technology. In Secondary Cycle One, the time indicated is 100 hours per year.

Instructional Materials, Equipment, and Laboratories

Teachers must use ministry-approved instructional materials. However, they are free to choose their own learning situations, pedagogical approaches, problems, and resources. They are not limited to a single pedagogical approach or instructional resource. The ministry finances the updating of laboratories and workshops needed to help students develop competencies in science and technology.

Use of Technology

The Québec education program for the elementary and secondary levels contains a competency involving the use of information and communication technology. Courseware is now eligible for approval by the ministry, which also finances the updating of schools' computers.

Teachers and Teacher Education

Education and Training for Fourth and Eighth Grade Mathematics and Science Teachers

A 4-year bachelor's program in elementary education is required to teach elementary school. The program trains generalists (to teach all general subjects, including mathematics and science). In secondary school, teachers must hold a bachelor's degree, preferably with a specialization in their subject area, including mathematics and science.

Teacher Professional Development in Mathematics, Science, and Technology

The most common forms of professional development for teachers are university studies, training provided by the ministry or school boards, and conferences. Peer training and participation in action-research projects also are becoming increasingly popular.

Examinations and Assessments

At the end of elementary school, the ministry administers compulsory examinations in mathematics. The examinations are scored by teachers using a marking guide. The ministry sometimes collects samples of students' work in order to better understand student learning in this area.

For the certification of studies, students must pass uniform examinations in mathematics and science and technology at the end of the second year of secondary cycle two (secondary 4). These examinations are marked by teachers using a marking guide provided by the ministry. Student evaluation is the responsibility of the schools, which must adopt a local evaluation policy.

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- 1 Ministère de l'Éducation du Québec. (2001). *Québec education program, preschool education, elementary education*. Québec: Gouvernement du Québec.
- 2 Ibid.
- 3 Ministère de l'Éducation du Québec. (2003). *Québec education program, secondary school education, cycle one*. Québec: Gouvernement du Québec.
- 4 In a geometric space of a given dimension (0, 1, 2, or 3), a geometric figure is a set of points representing a geometric object, such as a point, line, curve, polygon, or polyhedron.
- 5 SI refers to the international system of units.
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Appendix: Organizations and Individuals Responsible for TIMSS 2007

Introduction

TIMSS 2007 was a collaborative effort involving hundreds of individuals around the world. This appendix recognizes the individuals and organizations for their contributions. Given the work on TIMSS 2007 has spanned approximately five years and has involved so many people and organizations, this list may not include all who contributed. Any omission is inadvertent.

Of the first importance, TIMSS 2007 is deeply indebted to the students, teachers, and school principals who contributed their time and effort to the study.

Management and Coordination

TIMSS is a major undertaking of IEA, and together with PIRLS, comprises the core of IEA's regular cycle of studies. PIRLS, which regularly assesses reading at the fourth grade, complements the TIMSS assessments.

The TIMSS & PIRLS International Study Center at Boston College has responsibility for the overall direction and management of the TIMSS and PIRLS projects. Headed by Drs. Michael O. Martin and Ina V.S. Mullis, the study center is located in the Lynch School of Education. In carrying out the project, the TIMSS & PIRLS International Study Center worked closely with the IEA Secretariat in Amsterdam, which provided guidance overall and was responsible for verification of all translations produced by the participating countries. The IEA Data Processing and Research Center in Hamburg was responsible for processing and verifying the internal consistency and accuracy of the data submitted by the participants. Statistics Canada in Ottawa was responsible for school and student sampling activities. Educational Testing Service (ETS) in Princeton, New Jersey provided psychometric methodology recommendations addressing calibration, scaling, and survey design changes implemented in TIMSS 2007, and assisted in executing the item calibration analyses and made available software for scaling the achievement data.

The Project Management Team, comprised of the Directors and Senior Management from the TIMSS & PIRLS International Study Center, the IEA Secretariat, the IEA Data Processing and Research Center, Statistics Canada, and ETS met twice a year throughout the study to discuss the study's progress, procedures, and schedule. In addition, the Directors of the TIMSS & PIRLS International Study Center met with members of IEA's Technical Executive Group twice yearly to review technical issues.

Dr. Graham Ruddock from the National Foundation for Educational Research in England (NFER) was the TIMSS 2007 Mathematics Coordinator and Dr. Christine

O'Sullivan from K-12 Consulting was the TIMSS 2007 Science Coordinator. Together with the Science and Mathematics Item Review Committee, a panel of internationally recognized experts in mathematics and science research, curriculum, instructions, and assessments, they provided excellent guidance throughout TIMSS 2007.

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 Co-Coordinators, known as the NRCs. The NRCs had the complicated and challenging task of implementing the TIMSS 2007 study in their countries in accordance with TIMSS guidelines and procedures. The quality of the TIMSS 2007 assessment and data depends on the work of the NRCs and their colleagues in carrying out the very complex sampling, data collection, and scoring tasks involved. In addition, the Questionnaire Development Group, comprised of NRCs, provided advice on questionnaire development.

Continuing the tradition of truly exemplary work established in previous TIMSS assessments, the TIMSS 2007 NRCs (often the same NRCs as in previous assessments), performed their many tasks with dedication, competence, energy, and goodwill, and have been commended by the IEA Secretariat, the TIMSS & PIRLS International Study Center, the IEA Data Processing and Research Center, and Statistics Canada for their commitment to the project and the high quality of their work.

Funding

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