

MATHEMATICS FOR ALL BUT MORE MATHEMATICS FOR SOME – A LOOK AT SINGAPORE’S SCHOOL MATHEMATICS CURRICULUM

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In Singapore, the study of mathematics is compulsory both in the primary and secondary schools. However, the breadth and depth of mathematics taught to pupils vary according to their ability. The school mathematics curriculum has mathematical problem solving as its primary goal. The learning of concepts, acquisition of mathematical skills, use of thinking skills and problem solving heuristics are emphasised. This paper discusses school mathematics curricula in Singapore.

Introduction

Singapore’s Education System has evolved over time and so have school mathematics curricula in Singapore. The present day School Mathematics Curriculum can best be described as one that caters for the needs of every child in school. It is based on a framework that has mathematical problem solving as its primary focus. The attainment of problem solving ability is dependent on five inter-related components – Concepts, Skills, Processes, Attitudes and Metacognition (Ministry of Education, 2000a; 2000b). For

all pupils in school, irrespective of their abilities, mathematics education aims to enable pupils to:

- Acquire and apply skills and knowledge relating to number, measurement and space in mathematical situations that they will meet in life.
- Acquire mathematical concepts and skills necessary for a further study in Mathematics and other disciplines.
- Develop the ability to make logical deduction and induction as well as to explicate their mathematical thinking and reasoning skills through solving of mathematical problems.
- Use mathematical language to communicate mathematical ideas and arguments precisely, concisely and logically.
- Develop positive attitudes towards Mathematics including confidence, enjoyment and perseverance.
- Appreciate the power and structure of mathematics, including patterns and relationships, and to enhance their intellectual curiosity.

Developments in school mathematics curriculum during the last five decades

A school curriculum can be defined in terms of its aims, content and resources, teaching and learning strategies, and assessment practices (Wong, 1991). However it also exists within a broader context involving the physical, political, cultural, economic, and social environments that define and constraint its role in educating the people. It is clear from the review of the developments in the education system of Singapore in the last five decades (Kaur, 2003a) that the aims of the school curriculum are shaped by economic policies of the government that are necessary for the survival of Singapore in a fast changing world. School mathematics curriculum as part of the school curriculum has played a significant role in the economic development and progress of Singapore during the last five decades. A review of developments in school mathematics syllabuses follows.

Syllabuses

THE BEGINNING

Up to the 1950s, schools in Singapore were mainly vernacular in nature, i.e. there were Chinese, Malay, Tamil and English schools. The language of instruction

in Chinese schools was Chinese and their curricula were adopted from China. Likewise the language of instruction in English schools was English and their curricula were adopted from Britain. Therefore several mathematics syllabuses were in use across Singapore, with each school adopting their own. The first local set of syllabuses for mathematics was drafted in 1957 and published in 1959 (Lee & Fan, 2002). This set of syllabuses were for Primary and Secondary schools contained in a single booklet. The syllabuses adopted a spiral approach and were for all schools irrespective of their language streams.

In 1959, after the *People's Action Party* came into power, the government placed emphasis on educating the masses. In schools, the study of mathematics, science and technical subjects were emphasised. The first local set of syllabuses was used across all schools and little consideration was given to differences in the mathematical abilities of the pupils. The primary school mathematics syllabuses prepared pupils for the end of primary school national examination called the Entrance Examination. The secondary school mathematics syllabuses referred to as Syllabus B prepared pupils for the mathematics examinations of the Cambridge Certificate of Education conducted by the University of Cambridge Local Examination Syndicate (UCLES).

CHANGES IN LINE WITH WORLD TRENDS

A revision of the first local set of syllabuses for secondary schools took place in late 1960s in response to the *Math Reform of the 1960s*. The revised syllabus known as Syllabus C was implemented in the early 1970s (Lee & Fan, 2002). Towards the end of the 1970s the syllabus underwent yet another revision resulting in Syllabus D.

At the secondary school, all pupils take elementary mathematics. At the upper secondary level, the more able pupils also take Additional Mathematics. Both courses are based on the Ordinary Level ('O' Level) syllabuses of the University of Cambridge Local Examination Syndicate (UCLES). The Ministry of Education (MOE) issues the syllabus for the Lower Secondary levels. This syllabus covers topics in Arithmetic, Mensuration, Algebra, Graphs, Geometry, Statistics and Trigonometry. For each topic, the syllabus describes the instructional objectives, lists the main concepts and learning outcomes. These topics are a subset of the syllabus for the 'O' Level UCLES mathematics examination.

At the primary school, all pupils take mathematics and the emphasis is on Number, Fractions, Decimal fractions, Measurement, Geometry and very basic graphical representations of data. The syllabus is issued by MOE.

MATHEMATICS FOR EVERY CHILD

In 1981, when the New Education System (Ministry of Education, 1979) was implemented, MOE produced a mathematics syllabus for the Express and Special Courses in the secondary school by arranging the topics in Syllabus D into a four-year programme. At the same time, a sub-set of the topics in Syllabus D was selected for the weaker Normal Course pupils for the 'N' Level examination.

In line with the New Education System, the primary school mathematics syllabus was also reorganised. All pupils took the same course (Normal Course) for the first three years of their primary schooling. At the end of Primary Three they were streamed into one of the three courses: Normal, Extended or Monolingual. Pupils in the Normal, Extended and Monolingual Courses did the same mathematics syllabus, the only difference being pupils in the Normal Course completed primary school in six years while those in Extended and Monolingual Courses completed primary school in eight years.

In 1988, the Curriculum Development Division of the Ministry of Education set up a Mathematics Syllabus Review Committee to review and revise the mathematics syllabuses in use since 1981. The goals of the committee were to study the adequacy of the syllabuses in meeting the needs of the pupils, and to revise the syllabuses to reflect appropriate recent trends in mathematics education (Wong, 1991). It was during this review that the committee felt that besides elaborating the aims and objectives, a framework was necessary to describe the philosophy of the revised curriculum. Hence, the framework shown in Figure 1 that spells out the primary focus of the mathematics curriculum as *mathematical problem solving*. In 1990, the revised Mathematics Syllabus for the New Education System was implemented.

In response to the report, *Improving Primary School Education* (Ministry of Education, 1991), changes were made to the courses both at the primary and secondary schools. Streaming in the primary school was delayed by a year and from 1991 pupils in the primary school were streamed at the end of Primary Four. Primary school was now comprised of two stages: the Foundation Stage (Primary 1 to Primary Four) and Orientation Stage

(Primary Five and Primary Six). All pupils in the Foundation Stage did the same mathematics syllabus. Pupils in the Orientation Stage were streamed according to their ability and were put in one of the three streams: EM1, EM2 or EM3. Pupils in the EM1 and EM2 streams did the same mathematics syllabus while those in the EM3 stream did a subset of the syllabus for the EM1 and EM2 streams.

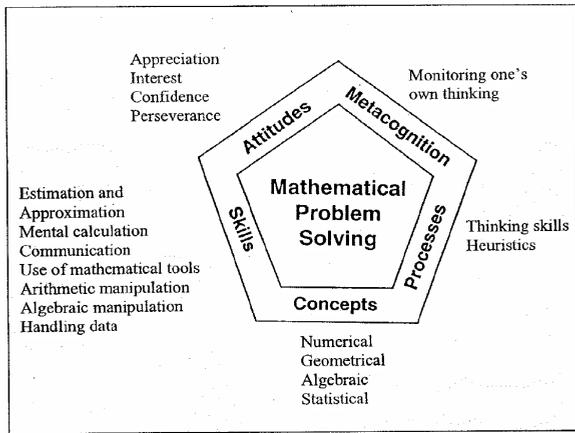


Figure 1. Framework of the Mathematics Curriculum (Ministry of Education, 2000a; 2000b).

Arising from the changes made in the primary school, the Normal (Technical) Course was created for the secondary school. In 1992, the mathematics syllabus for the Normal (Technical) Course pupils was produced by MOE (Ministry of Education, 1992). The Normal Stream mathematics syllabus was also renamed as Normal (Academic) stream mathematics syllabus A (4010). The Normal (Technical) stream mathematics syllabus is a sub-set of the Normal (Academic) stream syllabus. The Normal (Technical) stream mathematics syllabus T (4012) was implemented in 1994 when the Normal (Technical) stream came into being at the secondary one level for the first time.

TRIMMING THE CONTENT

In 1998, the mathematics syllabus underwent a content reduction exercise. The following rationale guided it.

- The learning of mathematics is sequential and hierarchical in nature. Therefore, essential topics and skills removed from one level were

transferred to another level in order to ensure continuity in the learning of the subject.

- Topics that were core content, i.e. essential as the foundation for Further Mathematics learning; developed the desired outcomes of the syllabuses; and provided continuity and completeness, were retained.
- Topics that were less fundamental and not connected to other topics in the syllabus; which placed heavy emphasis on mechanical computation; which overlapped with those taught at other levels; that were too abstract for the intended level and concepts/skills that were taught in other subjects, were removed from the syllabus.

Based on the above considerations, the following topics were moved from the primary school mathematics syllabus to the secondary school mathematics syllabus:

- Statistics – Solving problems using information given in pie charts
- Fractions – Division of a fraction by a fraction
- Geometry – Using photographs to identify flat and curved faces of a 3-D object
 - 2-D representation of a 3-D solid on an isometric grid
 - Geometrical construction using compasses
- Decimals – Division up to 2 decimal places by a 2-digit whole number
- Percentage – Use of the terms ‘profit’ and ‘loss’
 - Find percentage profit/loss
 - Reverse problems involving percentage profit/loss
- Algebra – Algebraic expressions up to 3 variables
 - Evaluation of algebraic expressions and formulae
 - Word problems involving algebraic expressions up to 3 variables

Also, based on the above considerations, the following topics were removed from the then existing syllabus for the ‘O’ Level Mathematics (D) Syllabus (4024): Set language and notation, Function notation, Limits of accuracy, Matrices & Use of matrices in Transformations.

The reduced content syllabuses were implemented in January 1999 at all levels in the primary school and Secondary 1 to Secondary 3 levels in the secondary school. For the primary schools, the school-based Primary Four streaming examination and Primary School Leaving Examination (PSLE) were based on the reduced content from 1999. For the secondary schools,

the syllabuses with reduced content were examined at the ‘O’ and ‘N’ Levels in the year 2000. There were no changes in the mode of assessment and the format of the examination.

MATHEMATICS FOR KNOWLEDGE-BASED ECONOMIES

Every ten years or so, the mathematics syllabuses undergo a periodic review to ensure that they remain relevant so as to prepare our pupils for the challenges and opportunities of the future and also to be in line with the national objectives. In 1998, following the content reduction exercise, a revision of the syllabuses was undertaken to:

- Update the content to keep abreast with the latest developments and trends in Mathematics education.
- Explicate the thinking processes inherent in the subject and to encourage the use of IT tools in the teaching and learning of Mathematics.
- Ensure the content meets the perceived needs of Singapore in the next millennium

Resulting from the revision, a couple of changes were made to the reduced content syllabus. It must be noted that the revised syllabus and reduced content syllabus were almost the same. A re-organisation of the content was mainly carried out. There was minimal increase in the content to emphasise the development of the thinking skills and help in the attainment of the objectives. A critical appraisal of the framework was also undertaken. Two changes were made to the framework of the 1990 syllabus. Under the arm of Processes, *Deductive reasoning and Inductive reasoning* were replaced by *Thinking skills* which now covers a much wider range of skills that pupils will be encouraged to use when solving problems. Also, an additional attribute, perseverance was added to the arm of Attitudes.

The revised syllabuses (Ministry of Education, 2000a; 2000b) were implemented in 2001 at Primary 1, Secondary 1 and Secondary 3 levels. In 2002, pupils in Primary 2, Secondary 2 and Secondary 4 were taught the revised syllabus. The University of Cambridge Local Examinations Syndicate (UCLES) has accommodated the revision of the syllabus resulting in the General Certificate in Education (GCE) Ordinary Level Mathematics (4017) Syllabus. Significant changes have also been made to the Examination papers to drive the objectives of the syllabus that are in line with the national vision ‘Thinking Schools, Learning Nation’. At the end of the year

2002, Secondary 4 pupils took the examination based on the revised syllabus for the first time.

The present mathematics courses for primary and secondary pupils

Primary level

Pupils enter primary school after the age of six years. Primary school consists of six grade levels, i.e. Primary 1 to Primary Six. During the first four years of primary school, i.e. from Primary One to Primary Four, emphasis is placed on the learning of English Language, Mathematics and Mother Tongue.

FOUNDATION STAGE

All pupils from Primary One to Primary Four take a common course in mathematics. The syllabus (Ministry of Education, 2000a) of the course emphasises a good foundation in:

- **Whole Numbers** – number notation and place value up to 100 000, addition and subtraction of numbers up to 4 digits, multiplication of 4-digit numbers by 1-digit numbers, multiplication of 3-digit numbers by 2-digit numbers, division of numbers up to 4 digits by a 1-digit number and by 10, odd and even numbers, approximation and estimation, factors and multiples.
- **Money, Measures & Mensuration** – Units of measure [length – km, m, cm; mass – kg, g; time – h, min, s, day, week, month, year; area – square m, square cm; volume – l, ml, cubic cm, cubic m]; addition, subtraction, multiplication, division of length, mass, volume, time and money; perimeter and area of rectilinear figures [square, rectangle, related figures]; volume of liquid, cube and cuboid.
- **Fractions** – equivalent fractions, comparing and ordering unlike fractions, addition and subtraction of like and related fractions, product of a proper fraction by a whole number, mixed numbers and improper fractions.
- **Decimals** – number notation and place value up to 3 decimal places, comparing and ordering, addition and subtraction up to 2 decimal places, multiplication and division up to 2 decimal places by 1-digit whole

numbers, conversion between decimals and fractions, approximation and estimation.

- **Geometry** – concept of angles & measurement in degrees, symmetry, lines [perpendicular & parallel], geometrical figures [rectangle, square, parallelogram, rhombus, trapezium, triangle], properties of square and rectangle, solids – cube & cuboid.
- **Statistics** – tables [constructing, reading, interpreting], bar graphs [reading, interpreting & constructing].

ORIENTATION STAGE

At the end of Primary Four, pupils take a school-based streaming examination. In Primary Five pupils are streamed according to their ability into EM1, EM2 and EM3 streams. Pupils in the EM1 & EM2 streams do the same mathematics course. This course builds on their good foundation, extends their mathematical knowledge in the above topics, as well as introduces them to new topics such as Average/Rate/Speed, Ratio/Proportion/ Percentage and Algebra. These pupils take the Mathematics paper in their PSLE.

Pupils in the EM3 stream do a mathematics course that is a subset of the course for EM1 and EM2 pupils. The aim of this course is to provide pupils in EM3 with a strong foundation in basic mathematical concepts to enable them to continue with a study of mathematics at the secondary level. The content repeats some of the important topics in the foundation stage. These pupils take the Foundation Mathematics paper in their PSLE.

CURRICULUM TIME

The recommended curriculum time per week for mathematics at the different levels is as follows:

- Primary 1 – 3.5 hours
- Primary 2 – 4.5 hours
- Primary 3 & 4 – 5.5 hours
- Primary 5 & 6
 - EM1 stream – 4.5 hours
 - EM2 stream – 5.0 hours
 - EM3 – 6.5 hours

ENROLMENT BY COURSES

Table 1 shows the enrolment of primary six pupils by course. From the table it is apparent that the proportion of pupils in the EM3 course has decreased over the last five years. As pupils in the EM1 and EM2 courses do the same mathematics syllabus, it appears that more than four fifths of the pupils in every cohort for the last five years have had the opportunity to learn a substantial amount of mathematical concepts and skills, thereby laying a good foundation for further study of mathematics in the secondary school.

Table 1. Primary Six Enrolment by Course from 1998–2002 (Ministry of Education, 2002)

Year	EM1	EM2	EM3	Total
1998	6556 (16.3%)	26656 (66.4%)	6941 (17.3%)	40153 (100.0%)
1999	7528 (16.5%)	29957 (65.8%)	8061 (17.7%)	45546 (100.0%)
2000	9257 (16.9%)	36978 (67.4%)	8612 (15.7%)	54847 (100.0%)
2001	8952 (17.8%)	34740 (68.9%)	6731 (13.3%)	50423 (100.0%)
2002	9614 (18.0%)	37876 (71.1%)	5791 (10.9%)	53281 (100.0%)

Secondary level

Pupils sit a national examination called the Primary School Leaving Examination (PSLE) at the end of Primary six. The examination assesses pupils' suitability for secondary education and places them in appropriate secondary school courses that suit their learning abilities. Three Courses are available at the secondary school level. Pupils undergo four or five years of secondary education with different emphases:

- Special Course – a four-year course leading to the Singapore-Cambridge General Certificate of Education (GCE) 'O' level examination. In this course, pupils study their mother tongue at the first language level, in addition to the usual humanities, mathematics and science subjects.
- Express Course – also a four-year course leading to the GCE 'O' level examination. In this course, pupils study their mother tongue at the second language level and offer a curriculum similar to that in the Special course.

- Normal Course – a four-year course leading to the GCE ‘N’ level examination. A fifth year is available to pupils who do well in this examination to prepare for and take the GCE ‘O’ level examination. Pupils in this course follow either the Normal (Academic) or Normal (Technical) curriculum. In the N(A) curriculum, they will learn English, mother tongue, mathematics and a range of subjects similar to those in the Special and Express courses. In the N(T) course, pupils will learn English, mother tongue at a basic level emphasizing oral/aural competence and reading comprehension, mathematics, computer applications and subjects with a technical and practical bias such as technical studies.

COMPULSORY MATHEMATICS COURSES

As mathematics is a compulsory subject for pupils in school, the mathematics curriculum at the secondary school level is differentiated to cater to the needs and abilities of pupils in the different courses. Core mathematical concepts are common to all courses and the content for the Special Course is identical to the Express Course. The content for the Normal (Academic) Course is a subset of the content for Special/Express Course while that of the Normal (Technical) Course is a subset of the Normal (Academic) Course. The mathematics syllabus (UCLES & MOE [Singapore] – General Certificate of Education Ordinary Level & Normal Level Mathematical subjects syllabuses for examination in 2002) for pupils in the three courses are as follows:

Special/Express Course

Numbers; Squares, square roots, cubes and cube roots; Vulgar and decimal fractions and percentages; Ordering; Standard form; The four operations; Estimation; Ratio, proportion and rate; Percentages; Use of a scientific calculator; Everyday mathematics; Graphs in practical situations; Graphs of functions; Coordinate geometry; Algebraic representation and formulae; Algebraic manipulation; Indices; Solutions of equations and inequalities; Geometrical terms and relationships; Geometrical constructions; Bearings; Symmetry; Angle; Locus; Mensuration; Trigonometry; Statistics; Probability; Transformations and Vectors in 2 dimensions.

Normal (Academic) Course

Numbers; Squares, square roots, cubes and cube roots; Vulgar and decimal fractions and percentages; Ordering; Standard form; The four rules; Estimation; Ratio, proportion and rate; Percentages; Use of a scientific calculator; Everyday mathematics; Graphs in practical situations; Graphs of functions; Coordinate geometry; Algebraic representation and formulae; Algebraic manipulation; Indices; Solutions of equations; Geometrical terms and relationships; Geometrical constructions; Bearings; Symmetry; Angle; Mensuration; Trigonometry; Statistics; and Transformations.

Normal (Technical) Course

Numbers; Squares, square roots, cubes and cube roots; Vulgar and decimal fractions and percentages; Ordering; Standard form; The four rules; Estimation; Ratio, proportion and rate; Percentages; Use of a scientific calculator; Everyday mathematics; Graphs in practical situations; Graphs of functions; Algebraic representation and formulae; Algebraic manipulation; Indices; Solutions of equations; Geometrical terms and relationships; Geometrical constructions; Net, plan and elevation; Bearings; Symmetry; Angle; Mensuration; Trigonometry and Statistics.

For all the three courses most of the topics taught at the various year levels for mathematics are similar. However the depth to which they are taught at a particular year level differs. The following extract from the syllabuses (Ministry of Education, 2000b) highlights the varying depth.

SECONDARY ONE – ALGEBRA (ALGEBRAIC EXPRESSIONS AND FORMULAE)

Special/Express Course

Use letters to represent numbers

Express basic arithmetic processes algebraically

Substitute numbers for words and letters in formulae and expressions

Simple algebraic manipulation – *Manipulate* simple algebraic expressions (include collecting like terms and removing brackets)

Simple linear equations – *Solve* simple linear equations

Solve problems involving linear equations – emphasise understanding of the problem leading to formulation of mathematical expressions/equations.

Normal (Academic) Course

Use letters to represent numbers

Express basic arithmetic processes algebraically

Substitute numbers for letters in formulae and expressions

Simple algebraic manipulation – *Manipulate* simple algebraic expressions (include collecting like terms and removing brackets)

Normal (Technical) Course

Concept and notation – Use letters to represent numbers and *Express* basic arithmetic processes algebraically

Substitution – *Substitute* numbers for letters in expressions and formulae (exclude expressions with brackets & exclude expressions involving squares and high powers)

Simplification – *Simplify* simple algebraic expressions (include collecting like terms, exclude removing of brackets at this level, exclude expressions involving squares and higher powers).

CURRICULUM TIME

The recommended curriculum time for mathematics in the secondary school is as follows:

Special/Express Course	– 2.5 to 3 hours per week
Normal (Academic) Course	– 2.5 to 3 hours per week
Normal (Technical) Course	– 4 to 5 hours per week

ENROLMENT BY COURSES

Table 2 shows the enrolment of Secondary One pupils by course. From the table it appears that for each cohort of pupils approximately 60 % of them do a mathematics course that prepares them for the UCLES Ordinary level Mathematics Examination. This course covers the widest range of topics in both breadth and depth at the secondary school level. From 1998 till 2002, each year approximately 40% of the cohort of pupils did mathematics courses that are part of the ‘O’ Level Course. These courses cover a range of topics in sufficient breadth and depth and prepare pupils for the ‘N’ Level mathematics examinations.

Table 2. Secondary One enrolment by course from 1998–2002 (Ministry of Education, 2002)

Year	Special Course	Express Course	Normal (Academic) Course	Normal (Technical) Course	Total
1998	4139 (9.8%)	21635 (51.2%)	9673 (22.9%)	6837 (16.1%)	42284 (100.0%)
1999	3782 (9.7%)	19923 (51.2%)	8925 (22.9%)	6320 (16.2%)	38950 (100.0%)
2000	4233 (9.5%)	22561 (50.7%)	9864 (22.2%)	7840 (17.6%)	44498 (100.0%)
2001	5201 (9.8%)	27641 (52.0%)	11986 (22.5%)	8326 (15.7%)	53154 (100.0%)
2002	4491 (9.1%)	26363 (53.4%)	11015 (22.3%)	7509 (15.2%)	49378 (100.0%)

MORE MATHEMATICS FOR SOME IN THE SECONDARY SCHOOL

Additional Mathematics in Years 9 and 10

Pupils in the Special and Express courses are able to do an Additional Mathematics course if they so desire in Year 9. This is a two-year course. At the end of the course, pupils take the GCE ‘O’ Level Additional Mathematics (4018) examination. The syllabus for the course consists of 15 themes or topics. They are: Set language and notation; Functions; Quadratic functions; Indices and surds; Factors of polynomials; Simultaneous equations; Logarithmic and exponential functions; Straight line graphs; Circular measure; Permutations and Combinations; Binomial expansions; Vectors in 2 dimensions; Matrices; Differentiation and Integration.

From the year 2004, pupils in the Normal (Academic) course, like their peers in the Special and Express courses, will be able to take Additional Mathematics in Year 9. These pupils will take Additional Mathematics at the GCE ‘N’ level examination. The content of Additional Mathematics – GCE ‘N’ Level is a subset of the content of Additional Mathematics – GCE ‘O’ Level.

Concluding remarks

Singapore’s education system has evolved over time into one that offers a sound education for all in school. In tandem, Singapore’s school mathematics curriculum has also evolved over time. The school mathematics curriculum, at present, emphasises a balance between mastery over basic skills and concepts

in Mathematics and the application of higher order thinking skills to solve mathematical problems. Every child in school does mathematics that is suited to his or her ability. The result of which is *mathematics for all but more mathematics for some*.

Singapore's lead in the Third International Mathematics and Science Study (TIMSS) (Kelly, Mullis & Martin, 2000) and Third International Mathematics and Science Study – Repeat (TIMSS-R) (Mullis, Martin, Gonzalez, Gregory, Garden, O'Connor, Chrostowski & Smith; 2000) has signaled to both mathematics teachers and educators in Singapore that the school mathematics curriculum is somewhat right. But this does not mean that the process of refining it will come to a halt. A careful study of the TIMSS and TIMSS-R test data has confirmed that Singapore pupils have indeed performed very well only on items that were routine to them and they were tested on what they had been taught at school (Kaur & Yap, 1999; Pereira-Mendoza, Kaur & Yap 1999; Kaur, 2002; Kaur, 2003b). Hence the present revision of the school mathematics curriculum (Ministry of Education, 2000a; 2000b) and future ones hope to address some of these concerns.

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