Towards universal participation in post-16 mathematics: lessons from high-performing countries

Country profile: Hong Kong

Population (mid-2011):	7,071,600[1]
Population aged 5-19:	998,000[2]
Population aged 15-19:	423,700[3]
Senior secondary school students:	227,278[4]
Registered school students (2011-12):	789,968[5]
Number of schools (state and private[6]):	1,153[7]

In the 2011/12 school year, there were 568 primary schools (40 of which were international schools), 524 secondary schools (27 of which were international schools) and 61 special schools (including one international school). Primary and secondary education is free. State-funded education was extended from 9 years to 12 years in order to include senior secondary school and senior secondary vocational courses from September 2008.

Putonghua (meaning 'common language') is the official spoken language in China, while Cantonese (meaning 'the language of Canton', which is the region now known as Guangzhou) is the dialect most widely spoken in Hong Kong. As the mother tongue, Chinese is promoted as the medium of instruction in local schools. However, both Chinese and English are the official languages of Hong Kong. Hong Kong has historic English influences

[1] Population estimates for mid-2011 from: http://www.censtatd.gov.hk/hong_kong_statistics/statistics_by_subject/population_and_vital_events/index.jsp
[2] Population estimates for mid-2011 from: http://www.censtatd.gov.hk/hong_kong_statistics/statistics_by_subject/population_and_vital_events/index.jsp
[3] Population estimates for mid-2011 from: http://www.censtatd.gov.hk/hong_kong_statistics/statistics_by_subject/population_and_vital_events/index.jsp
[4] The figure refers to S4-6 students during the 2011/12 academic year in local and international schools and does not include school leavers in vocational educational institutions: http://www.edb.gov.hk/index.aspx?nodeID=1039&langno=1
[5] This comprises primary school students: 322,881: http://www.edb.gov.hk/index.aspx?nodeID=1038&langno=1 and 435,288 secondary school students in S1-S6 and the final cohort of 31,799 students in S7: http://www.edb.gov.hk/index.aspx?nodeID=1039&langno=1
[6] In the terminology of Hong Kong's education system, this comprises 'local' and 'international' schools.
[7] Although some schools operate a 'through-train' progression from primary to secondary education, these schools are either counted as primary or secondary schools. The figure here is based on data from: http://www.edb.gov.hk/index.aspx?nodeID=92&langno=1

and a present status as an international city. This means that the importance attached to the English language is a defining feature of the education system in Hong Kong. The policy aim is therefore for students to be biliterate (in Chinese and English) and trilingual (in Cantonese, Putonghua and English). English is the medium of instruction in a significant minority of schools and by definition these are high performing schools who can, to a greater or less extent, select their students. Secondary school places are allocated according to parents' preferences and students' attainment in standardised tests during primary school.

Hong Kong no longer operates a system with five years up to the equivalent of GCSEs, two years equivalent to A-levels and three years at undergraduate level. The system, now in operation and known as the New Academic Structure, comprises:

- Primary (six years from P1 to P6 at ages 6-12)
- Junior Secondary (three years from S1 to S3 at ages 12 – 15)
- Senior Secondary (three years from S4 to S6 at ages 15 – 18)
- Tertiary education (four years for undergraduate degrees).

The changes were announced in May 2005 in order to allow time for them to commence with the Secondary 4 cohort in September 2009. This cohort became the first S6 students to complete the new Hong Kong Diploma of Secondary Education (HKDSE) in May 2012.

Mathematics is a core subject for students in primary and secondary schools. This means that it is compulsory for all school students, whether they choose a more academic or more applied programme at upper secondary level. A small number of students leave school at the end of lower secondary level to begin courses at vocational education institutions. These students may be required to study some mathematics as part of the requirements for their chosen career paths.

In addition to public education there is also a very substantial amount of 'shadow education'. In the 1990s, surveys found that around 40% of Hong Kong's upper secondary students received private tutoring.[8] Intense competition for university places has been an important factor in the on-going use of private tutoring.[9]

1. What is the national policy for, and structure of, mathematics education provision for 16-18/19 year-old (pre-university level) learners?

→ Is upper secondary education compulsory or optional?
→ What is the structure of upper secondary programmes?
→ Is any mathematics compulsory in the upper secondary age group?
→ What, if any, are the mathematics options in upper secondary education?

[8] Bray, M. (1999, 2007). The shadow education system: private tutoring and its implications for planners: UNESCO: IIEP.
[9] Ho, N.H. (2010). Hong Kong's shadow education. The Hong Kong Anthropologist (4, 62-85).

Senior secondary education

Senior secondary education is not compulsory and a small number of students choose to study abroad or to stop studying. However, Hong Kong's Education Development Bureau believes the proportion of students accepting the entitlement to senior secondary education to be 'extremely high'. Thus very few students leave education and training at the end of junior secondary education.[10] Furthermore, very few students leave school at lower secondary level to enter vocational education in colleges or other training providers.[11]

This contrasts with the position prior to reform, when about 42% of students progressed from the lower secondary HKCEE (Hong Kong Certificate of Education Examination; equivalent to GCSE in England) to the upper secondary HKALE (Hong Kong A level Examination; equivalent to A level in England).[12]

Three categories of subjects were offered in the HKDSE in 2012. These were:

- Category A: 24 New Senior Secondary subjects
- Category B: 30 Applied Learning subjects
- Category C: six Other Language subjects.

Under the New Senior Secondary (NSS) Curriculum, school candidates for the HKDSE must take four core subjects: Chinese Language, English Language, Mathematics and Liberal Studies, and a maximum of four elective subjects.

In addition to the four core subjects, in 2012 over 90% of the school candidates registered for two or three elective subjects (about 64% for two elective subjects and about 27% for three elective subjects). Among the NSS elective subjects, the most popular in 2012 were: Economics (30% of students); Chemistry (24%); Business, Accounting and Financial Studies (24%); and, Biology (24%). By contrast, about 7% of candidates registered for a Category B Applied Learning subject.[13]

New Senior Secondary Mathematics Curriculum (NSSMC)

NSSMC was developed by the Curriculum and Development Council and Hong Kong Examinations and Assessment Authority Committee on Mathematics Education (Senior Secondary) in support of the new three-year senior secondary curriculum. The NSSMC for S4 – S6 is a continuation of the existing Mathematics Curriculum at junior secondary level (S3 – S5).[14]

The Curriculum and Assessment Guide (Secondary 4 – 6) for the Mathematics Education Key Learning Area sets out a rationale for studying Mathematics as a core subject at senior

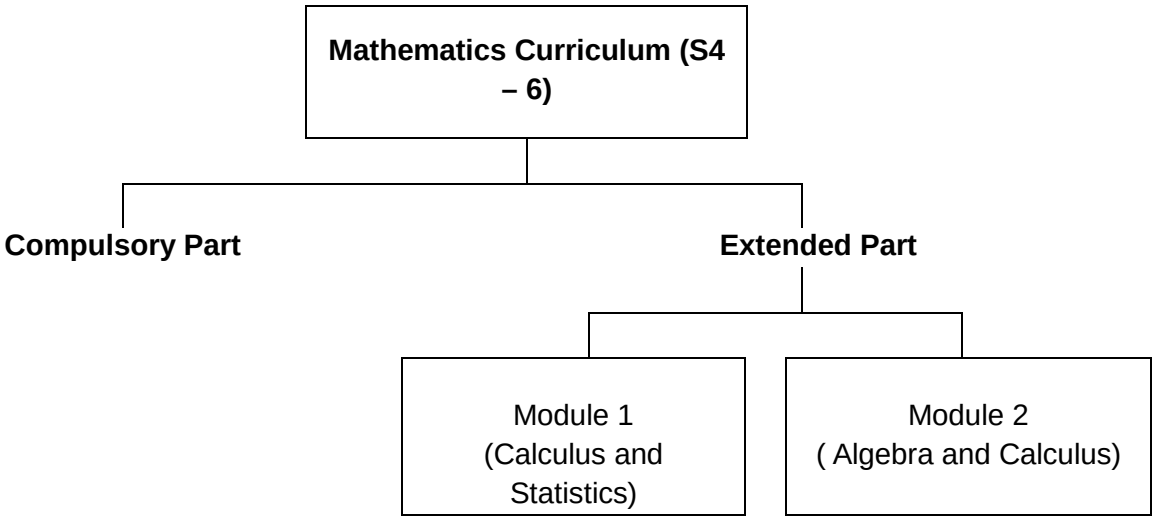
[10] Correspondence with Hong Kong's Education Bureau.
[11] Correspondence with Professor Leung.
[12] Hodgen, J., Pepper, D., Sturman, L., & Ruddock, G. (2010). Is the UK an outlier? An international comparison of upper secondary mathematics education. England: Nuffield Foundation.
[13] http://www.hkeaa.edu.hk/DocLibrary/Media/PR/20111201_PR_Registration_of_2012_HKDSE_FULL_eng_final.pdf
[14] Correspondence with Hong Kong's Education Bureau.

secondary level, with points relating to the importance of mathematics in a technology and information-rich society as:

- A platform for lifelong learning in a changing world
- A form of literacy for citizenship and the workplace
- A foundation for other disciplines
- An intellectual endeavour central to human culture.

Distinctive features of the Mathematics Education Key Learning Area's stated overall aims include: thinking creatively and critically; solving problems in daily life, mathematical contexts and other disciplines; and, developing a positive attitude towards learning mathematics and an appreciation of aesthetic nature and cultural aspects of mathematics.[15] In addition the curriculum aims to develop students' competence and confidence in dealing with mathematics needed in life.[16]

The structure of the Mathematics Curriculum (S4 – S6) can be represented diagrammatically as follows:



Students may take the Compulsory Part only, the Compulsory Part with Module 1 (Calculus and Statistics) or the Compulsory Part with Module 2 (Algebra and Calculus). All students must study the Compulsory Part and students are allowed to take only one module from the Extended Part.[17] This structure is unique among senior secondary subjects and is intended to accommodate students' range of attainment and interests. It was particularly important to address this as, with the transition to the New Academic Structure, students began to take mathematics as a compulsory subject not just, as previously, until the end of S5 but also in S6. An alternative structure with extended options external to the compulsory content was initially considered but low recruitment to these options was anticipated.[18]

[15] http://www.edb.gov.hk/FileManager/EN/Content_5999/math_final_e.pdf
[16] Correspondence with Hong Kong's Education Bureau.
[17] Correspondence with Hong Kong's Education Bureau with reference to this source: http://www.edb.gov.hk/index.aspx?nodeID=6120&langno=1
[18] Correspondence with Professor Leung.

2. What are the overall participation rates in mathematics study for 16-18 year-olds both as proportions of students and proportions of the age cohort?

→ What are current levels of participation in mathematics overall amongst the upper secondary cohort and age group?
→ What are the current levels by gender?
→ How have these participation rates changed over time?

HKDSE

The following table refers to candidates for the HKDSE in 2012 (i.e. S6 students entered for the HKDSE in the 2011/12 school year).[19]

	Number of HKDSE 2012 candidates	Percentage of HKDSE 2012 cohort
Mathematics- Compulsory or Extended Part	72413	99.4%
Compulsory Part only	55796	76.6%
HKDSE 2012 cohort	72876	100%

All school candidates are required to take NSS Mathematics (i.e. no students can avoid taking Mathematics if they want to be admitted to local universities).[20] According to the Hong Kong Examinations and Assessment Authority, from the total of 72,876 candidates, there were 71,762 school candidates (98.5%) and 1114 non-school candidates (1.5%) enrolled for the 2012 HKDSE.[21] In theory, these few non-school HKDSE candidates could choose not to take Mathematics (though with possible implications for the academic and career paths that are open to them).

Vocational education

Mathematics is not a compulsory subject in vocational education. However, students may be required to study some mathematics as part of their wider vocational programmes and this will be dependent on their choice of programme.

Participation in advanced mathematics

The proportion of students who leave school at the end of S3 to begin courses at vocational education institutions is negligible and some will study mathematics as part of their programme. The proportion of students completing S3 who leave education and training altogether is also negligible. A conservative assumption would therefore be that over 95% of the upper secondary age cohort studies some mathematics. Similarly, approximately 22-

[19] http://www.hkeaa.edu.hk/DocLibrary/Media/PR/20111201_PR_Registration_of_2012_HKDSE_FULL_eng_final.pdf
[20] Correspondence with Hong Kong's Education Bureau.
[21] http://www.hkeaa.edu.hk/DocLibrary/Media/PR/20111201_PR_Registration_of_2012_HKDSE_FULL_eng_final.pdf

23% of the HKDSE upper secondary cohort study advanced mathematics, which is over 20% of the upper secondary age cohort. Detailed data was not available in time for this report, but experts and teachers believe this to be a reduction from previous participation rates.

3. What are the patterns of participation in terms of following different routes involving mathematics?

→ What are current levels of participation in different mathematics options amongst the upper secondary cohort and age group?

HKDSE[22]

	Number of HKDSE 2012 candidates	Percentage of HKDSE 2012 cohort
Compulsory Part and Extended Part-Module 1 Calculus and Statistics	7819	10.7%
Compulsory Part and Extended Part-Module 2 Algebra and Calculus	8376	11.5%
HKDSE 2012 cohort	72876	100%

4. What is the content and level of the different kinds of provision?

→ What is the structure and content of the mathematics options?
→ How is teacher education organised in order to offer the mathematics options?

Structure and content of the New Senior Secondary Mathematics Curriculum (NSSMC)

The NSSMC seeks a balance between breadth and depth, theoretical and applied learning and procedural and conceptual knowledge.[23]

The Compulsory Part and the Extended Part of the NSSMC are intended to cater for students who have different needs, interests and orientations. The inclusion of the Extended Part, with its choice of two optional modules, is designed to provide more flexibility and diversity in the curriculum. These two modules supplement the Compulsory Part and students, based on their individual needs and interests, are encouraged to take one of the two modules at most.[24]

Schools and teachers are encouraged to adapt the central mathematics curriculum and develop their own school-based curricula, taking into consideration the needs, abilities and interests of their students and their school contexts, through varying:

- content, contexts and examples;
- learning and teaching strategies;
- pace of learning and teaching; and
- modes of assessment.[25]

[22] http://www.hkeaa.edu.hk/DocLibrary/Media/PR/20111201_PR_Registration_of_2012_HKDSE_FULL_eng_final.pdf Note: This and the previous table are based on the same first release data. At the time of release, the data had not been consolidated. As a result, there is a small discrepancy between the two tables.
[23] http://www.edb.gov.hk/FileManager/EN/Content_5999/math_final_e.pdf
[24] Correspondence with Hong Kong's Education Bureau.
[25] http://www.edb.gov.hk/FileManager/EN/Content_5999/math_final_e.pdf

Furthermore, the NSSMC states that:

> *In view of the broad cross-curricular links with other disciplines, Mathematics teachers should collaborate with teachers of other Key Learning Areas to set achievable goals, draw up schedules of work, and design learning and teaching activities, so that students can apply their mathematics knowledge in different contexts.*[26]

Compulsory Part

The Compulsory Part of the Mathematics Curriculum (S4 – 6) comprises three strands, namely "Number and Algebra", "Measures, Shape and Space" and "Data Handling".

In the Compulsory Part, "Number and Algebra" includes the following learning units:
- Quadratic equations in one unknown
- Functions and graphs
- Exponential and logarithmic functions
- More about polynomials (eg the factor theorem)
- More about equations (eg quadratic equations with two unknowns, one linear and one quadratic)
- Variations
- Arithmetic and geometric sequences and their summations
- Inequalities and linear programming.

In the Compulsory Part, "Measures, Shape and Space" includes the following learning units:
- Basic properties of circles
- Locus
- Equations of straight lines and circles
- More about trigonometry.

In the Compulsory Part, "Data Handling" includes the following learning units:
- Permutation and combination
- More about probability
- Measures of dispersion
- Uses and abuses of statistics.

There is flexibility for students taking only the Compulsory Part to study Foundation Topics, Foundation Topics and some Non-foundation Topics, or Foundation Topics and the Non-foundation Topics. Teachers can judge for themselves the suitability and relevance of the Non-foundation Topics for their students. The contents of Module 1 and Module 2 are built upon the study of the Foundation and Non-foundation Topics in the Compulsory Part. It is advisable for students to study Foundation Topics and Non-foundation Topics in the Compulsory Part if they study either one of the modules from the Extended Part.[27]

Extended Part

The Compulsory part provides a foundation for the Extended Part. In the Extended Part, the two optional modules are designed to cater for students who intend to:
- pursue further studies which require more mathematics; or
- follow a career in fields such as natural sciences, computer sciences, technology or engineering.

[26] Page 93 of: http://www.edb.gov.hk/FileManager/EN/Content_5999/math_final_e.pdf
[27] http://www.edb.gov.hk/FileManager/EN/Content_5999/math_final_e.pdf

Module 1 (Calculus and Statistics) focuses on statistics and the application of mathematics, and is designed for students who will be involved in study and work which demand a wider knowledge and deeper understanding of the application of mathematics, in particular, statistics. Module 2 (Algebra and Calculus) focuses on mathematics in depth and aims to cater for students who will be involved in a mathematics-related discipline or career.

Extended Part- Module 1 (Calculus and Statistics)

Foundation knowledge area

- Binomial expansion
- Exponential and logarithmic functions

Calculus area

- Derivative of a function
- Differentiation of a function
- Second derivative
- Applications of differentiation

Integration and its applications

- Indefinite integrals and their applications
- Definite integrals and their applications
- Approximation of definite integrals using the trapezoidal rule

Statistics area

Further probability:
- Conditional probability and independence
- Bayes' theorem

Binomial, Geometric and Poisson Distributions and Their Applications:
- Discrete random variables
- Probability distribution, expectation and variance
- Binomial distribution
- Geometric distribution
- Poisson distribution

Applications of binomial, geometric and Poisson distributions:
- Basic definition and properties
- Standardisation of a normal variable and use of the standard normal table
- Applications of the normal distribution

Point and interval estimation:
- Sampling distribution and point estimates
- Confidence interval for a population mean
- Confidence interval for a population proportion

Extended Part- Module 2 (Algebra and Calculus)

Foundation knowledge area

- Surds
- Mathematical induction (only the first principle)
- Binomial theorem
- More about trigonometric functions
- Introduction to the number *e*

Calculus area

Limits and differentiation:
- Limits
- Differentiation
- Applications of differentiation

Integration:
- Indefinite integration
- Definite integration
- Applications of definite integration

Algebra area

Matrices and systems of linear equations:
- Determinants
- Matrices
- Systems of linear equations

Vectors:
- Introduction to vectors
- Scalar product and vector product
- Applications of vectors[28]

Time allocations for NSSMC

As a core subject, the Mathematics Curriculum (S4 – 6) accounts for up to 15% of the total lesson time available in the senior secondary curriculum. The suggested time allocations for the Compulsory Part and the Extended Part are as follows:

	Approximate lesson time
Compulsory Part	10 – 12.5% (270 – 338 hours over 3 years)
Compulsory Part with a module	15% (405 hours over 3 years)

It is expected that 10% of the total lesson time will be enough for the average student to complete the Compulsory Part. However, for those students who require more time, schools may allocate up to 12.5% of the total lesson for them to complete the Compulsory Part.

[28] http://www.edb.gov.hk/FileManager/EN/Content_5999/math_final_e.pdf

Students taking one of the optional modules are expected to be higher attaining students who can complete the Compulsory Part in no more than 10% of the total lesson time.[29]

Teacher training for secondary school mathematics

There are two modes of teacher training. The first is a four-year undergraduate degree and a one-year full-time or two-year part-time postgraduate diploma of education (PGDE). Graduates can be employed as provisional teachers whilst completing their PGDE. The second is a five-year undergraduate degree in education (B.Ed.).

Teacher training is provided by institutions including University of Hong Kong, Chinese University of Hong Kong (CUHK) and Hong Kong Institute of Education. These institutions operate within a basic framework for teacher training controlled by the government, which licenses teachers. Thus whilst the government, for example, defines the period of teaching practice as 8-10 weeks, the institutions decide how this will be organised and assessed. Furthermore, each institution has its own philosophy and emphasis. For example, CUHK admits graduates in mathematics or related subjects to its mathematics teacher training course. In doing so, it assumes a minimum level of subject knowledge, allowing the course to focus on pedagogic content knowledge.

Teachers generally train either for the primary or secondary sector but cross-sectoral training is also available. Teacher trainees preparing for secondary education are introduced to the NSS curriculum during the PGDE but since it does not involve a change in teaching methods, this focuses on essential points relating to the curriculum content. With respect to upper secondary mathematics, this includes the respective contents of the Core, M1 and M2 components. This point was also covered in professional development for serving teachers through workshops run by the government and the professional Hong Kong Association for Mathematics Education.[30]

5. How are the different mathematics options assessed?

→ How and when are students assessed for summative purposes?
→ Are any alternative assessment pathways available?

NSSMC and HKDSE

The NSSMC states that: 'The most important role of assessment is in promoting learning and monitoring students' progress. However, in the senior secondary years, the more public roles of assessment for certification and selection come to the fore' (p.122). It goes onto differentiate assessment for learning and assessment of learning. Where assessment of learning relates to public assessment, the intention was for it to include both public examinations and moderated school-based assessment (SBA). SBA is defined as 'assessments administered in schools and marked by the students' own teachers' (p.132).

The NSSMC indicates that a major change to public examinations in Mathematics has been necessary in order to accommodate the changes to the curriculum:

> *The Hong Kong Advanced Level Examination (HKALE) is designed for a relatively elite group of students, most of whom aspire to university study. However, the new assessments and examinations will accommodate the full*

[29] Correspondence with Hong Kong's Education Bureau and: http://www.edb.gov.hk/FileManager/EN/Content_5999/math_final_e.pdf
[30] Correspondence with Professor Wong.

> *spectrum of student aptitude and ability. The written papers in the public examination will contain multiple-choice and short questions which test candidates' basic knowledge of mathematics and long questions testing higher-order thinking skills. The SBA will provide room for a wide range of activities suited to the students in each school (p.129).*

The rationale for SBA is to enhance validity (including reliability) and to achieve a positive backwash effect into the curriculum (through the activities required for SBA). In SBA, the proposal is for two assessment tasks to be completed, one in S5 and one in S6, and for them to comprise one task on mathematical investigation or problem-solving and one task on data handling. These tasks would account for 15% of the total assessment (with the other 85% based on public examinations). However, although planned for the Compulsory Part of the NSSMC, there is no longer a definite timescale for the introduction of SBA as part of public assessment:

> *There is no time-line for the implementation of SBA in Mathematics and a review will be conducted in the school year 2012/13. During the transition years, the curriculum for Mathematics will remain intact and schools will be expected to conduct the SBA activities as integral parts of learning and teaching and internal assessment as recommended in the Curriculum and Assessment Guide.*[31]

A key factor was the teaching workforce's concern with the fairness of SBA and the associated workload.[32] Although SBA is still being implemented for internal assessment and formative purposes, the present mode of public assessment for the NSSMC is as shown below.

Compulsory Part:

	Component	Weighting	Duration
Public Examination	Paper 1 Conventional questions	65%	2¼ hours
	Paper 2 Multiple-choice questions	35%	1¼ hours

Module 1 (Calculus and Statistics):

	Component	Weighting	Duration
Public Examination	Conventional questions	100%	2 ½ hours

Module 2 (Algebra and Calculus):

	Component	Weighting	Duration
Public Examination	Conventional questions	100%	2 ½ hours

The HKDSE makes use of Standards-referenced Reporting of assessments. Standards-referencing aims at reporting candidates' results against a set of prescribed levels of achievement based on typical performance of candidates at those levels. For each of the

[31] This was published on 9/6/11 (http://www.hkeaa.edu.hk/en/HKDSE/Subject_Information/NSS/math/): http://www.hkeaa.edu.hk/DocLibrary/HKDSE/Subject_Information/math/2012hkdse-e-math.pdf

[32] Correspondence with Professor Leung.

levels, a set of descriptors has been developed that describes what the typical candidate performing at this level is able to do. Candidate's results indicate the standards achieved in terms of knowledge and skills regardless of the performance of the other candidates taking the same examination. This reporting system also enables stakeholders to understand explicitly what the candidates know and can do when they have achieved a certain level of performance.[33] Students' performances in the public examination in the Compulsory Part, Module 1 and Module 2 will be reported separately.[34]

6. What information is available on students' learning outcomes in secondary education?

→ What research or policy evidence is available on students' expectations, attitudes and attainment in relation to mathematics in lower and upper secondary education?

HKDSE

The first HKDSE examination results are now available. In 2012, 72,620 candidates sat the examination, of which 98% entered as school candidates. Results are reported in levels from Level 1 (the lowest threshold for attainment) to Level 5** (the highest threshold for attainment) and focus on the general population of 'day school candidates'.

26,431 day school candidates met the general entrance requirements for local four-year undergraduate university programmes, obtaining Level 3 or above in both Chinese Language and English Language, and level 2 or above in Mathematics Compulsory Part and Liberal Studies. This represents 37.7% of the day school candidature.

A total of 47,831 day school candidates obtained Level 2 or above in five subjects, including Chinese Language and English Language.

Among day school candidates, 0.8% attained Level 5** (the highest level) and 79.3% got Level 2 or above in Chinese Language, while 0.8% achieved Level 5** and 79.2% received Level 2 or above in
English Language.

In Mathematics Compulsory Part, 1.1% of day school candidates attained Level 5** and 79.7% got level 2 or above. As for Liberal Studies, 0.8% of day school candidates attained Level 5** while the percentage receiving Level 2 or above was 90.8%.

Of the 15,435 students who sat both the Compulsory Part and the Extended Part of Mathematics, 1.4% gained Level 5** in both parts, a little over 20% attained level 5, 5* or 5** in both parts and just under 50% attained Level 4 or above in both parts.[35]

Programme for International Student Assessment

Hong Kong participated in the OECD's PISA survey in 2001, 2003, 2006 and 2009 and has consistently performed highly in PISA mathematics. Of the Hong Kong students aged 15-16 who were surveyed as part of PISA 2009, approximately 65% were in S4 and 25% were in S3.

[33] http://www.hkeaa.edu.hk/en/hkdse/
[34] http://www.hkeaa.edu.hk/DocLibrary/Media/PR/20111201_PR_Registration_of_2012_HKDSE_FULL_eng_final.pdf
[35] http://www.hkeaa.edu.hk/DocLibrary/Media/PR/20120719_HKDSE_Results_ENG_FULL.pdf

Hong Kong's mean score of 555 on the PISA mathematics scale was ranked 3rd amongst 65 participating systems. This mean score was statistically significantly different from Shanghai-China and Singapore (ranked 1st and 2nd, respectively) but not statistically significantly different from Korea (ranked 4th on the PISA mathematics scale). 31% of Hong Kong students performed at the top two PISA mathematics proficiency levels (compared with 13% of OECD countries) and less than 10% performed at or below the bottom PISA mathematics proficiency level (compared with 22% OECD countries, though with wide variations). On average, boys achieved higher scores than girls by a similar margin to the OECD average of 12 points on the mathematics scale.[36]

When mathematics was the focus of the PISA survey in 2003, Hong Kong was the second highest performing system in mathematics. However, this was not accompanied by a high proportion of students expressing interest in the subject (or, more generally, considering school to be a good preparation for adult life). Students in Hong Kong were amongst those with the lowest levels of self-concept in mathematics (confirming a trend observed amongst the other Asian participants). However, Hong Kong students' self-efficacy for specific mathematical tasks was relatively high compared to students in many of the other 41 countries participating in the 2003 survey.[37]

Trends in Mathematics and Science Survey (TIMSS)

Hong Kong participated in the 1995, 1999, 2003, 2007 and 2011 surveys and has consistently performed highly in mathematics. The 2011 results are not available yet and the following results refer to the 2007 survey.

At Grade 4 (when students are aged approximately 10), Hong Kong's mean score of 607 on the TIMSS mathematics scale was ranked 1st amongst the participating systems (though not statistically significantly different from Singapore). Boys had higher performance than girls at Grade 4 and lower than girls at Grade 8 but the differences were not statistically significantly different.

The following results refer to Grade 8 (when students are aged approximately 14). Hong Kong's mean score of 572 was ranked 4th amongst the participating systems (statistically significantly lower than Taipei, Korea and Singapore). At Grade 8, 31% and 64% performed at or above the Advanced Benchmark and the High Benchmark, respectively (compared with an international median of 2% and 15% respectively). A relatively low proportion of students in Hong Kong valued mathematics highly. Similarly, a relatively low proportion of students had high self-confidence in mathematics and the gender difference, with girls expressing lower confidence than boys, was amongst the largest in the countries surveyed (based on questionnaire items similar to those used in connection with self-concept in the PISA survey).[38]

[36] OECD (2010), PISA 2009 Results: What Students Know and Can Do – Student Performance in Reading, Mathematics and Science
(Volume I) http://dx.doi.org/10.1787/9789264091450-en
[37] OECD. 2004. Learning for Tomorrow's World: First Results from PISA 2003. Paris: OECD
[38] Mullis, I. V. S., Martin, M. O., Foy, P., Olson, J. F., Preuschoff, C., Erberber, E., . . . Galia, J. (2008). TIMSS 2007 International Mathematics Report: Findings from IEA's Trends in International Mathematics and Science Study at the Fourth and Eighth Grades. Chestnut Hill, MA: TIMSS & PIRLS International Study Center, Boston College.

7. What vocational education options are available at upper secondary level?

- → What is the structure and content of the vocational courses available?
- → What status do vocational courses have in comparison to other options?
- → What are the participation levels in these courses?
- → How much mathematics is included in vocational education courses and at what levels?

Full-time study places are offered to school leavers through various pre-employment vocational education programmes, which are delivered mainly at the campuses of member institutes of the Vocational Training Council (VTC), including the Youth College (YC).

YC offered various programmes for Secondary 3 and secondary 5 school leavers under the system prior to reform. However, to align with the new senior secondary academic structure, YC introduced a credit-based programme, namely the Diploma in Vocational Education, in 2009/10 school year for school leavers at or above Secondary 3 level.[39]

The VTC, the City University of Hong Kong (CityU), the Hong Kong Polytechnic University (PolyU), Hong Kong Academy for Performing Arts (HKAPA) and HKIEd also offer publicly-funded sub-degree programmes.[40]

A small number of students leave school at the end of lower secondary level to begin courses at these institutions – of the order of 1% of S3 students. They may be required to study some mathematics as part of the requirements for their chosen career paths.

8. What drives the pattern of take-up? How is it linked to the needs of HE, employers and national policy objectives?

- → What are the official criteria, if any, for acceptance to the mathematics options?
- → Are there any unofficial / local criteria for acceptance to the mathematics options?
- → What information, advice or guidance is there about the mathematics options?
- → Are any mathematics recruitment policies targeted to specific groups or types of students?
- → Which subjects and options are students expected or required students to take?
- → Please note the views of, for example, further/higher education institutions, employers, parents or the public more generally
- → Are there 'unofficial' expectations to have particular mathematics qualifications for entry to particular HE courses?

Recruitment to the HKDSE Mathematics – Extended Part

With the implementation of the senior secondary academic structure in Hong Kong, a wider range of students can gain access to Mathematics at the senior secondary level than in the past. Accordingly, the Mathematics Curriculum (S4 – 6) offers a Compulsory Part for all students and an Extended Part for some students.[41]

The NSSMC states that: 'Some students may be interested in studying a module along with the Compulsory Part. However, they might like to get some ideas of what it is like first in S4

[39] http://www.gov.hk/en/about/abouthk/factsheets/docs/education.pdf
[40] http://www.vtc.edu.hk/admission/eng/course-ftps3-disciplines-overview-dve.html
[41] http://www.hkeaa.edu.hk/DocLibrary/Media/PR/20111201_PR_Registration_of_2012_HKDSE_FULL_eng_final.pdf

before they decide whether or not to take it'. Therefore: 'For such cases, a small portion of the lesson time may be allocated to the study of a module in S4' (p.95).

The two modules in the Extended Part are designed for students who need more mathematical knowledge and skills for their future studies and careers, and for those whose interests and maturity have been developed to a level that enables them to benefit from further mathematical study in different areas. The two modules aim at extending students' mathematics horizons beyond the Compulsory Part. Students have to handle more complicated problems in the modules than in the Compulsory Part. Schools are free to set up their own school-based criteria for selecting students to take the modules. The market-driven nature of secondary school admissions means that schools are encouraged to offer the modules and demonstrate that their schools have high achieving students who take these modules.[42]

Module 1 (Calculus and Statistics) is intended to cater for those students who will be involved in disciplines or careers which demand a wider scope and deeper understanding of mathematics, and for those who would like to learn more mathematical applications at the senior secondary level. It aims to:

- provide students with skills and concepts beyond the Compulsory Part
- emphasise applications rather than mathematical rigour with a view to widening students' perspectives on mathematics
- provide students with intuitive concepts of calculus and statistics, related basic skills and useful tools for their future studies and careers.

Module 2 (Algebra and Calculus) is designed to suit the needs of students who will be involved in mathematics-related fields and careers, and those who would like to learn more in-depth mathematics at the senior secondary level. It aims to:

- provide students with skills and concepts beyond the Compulsory Part
- emphasise understanding of mathematics for further progress in mathematically inclined disciplines
- provide students with a concrete foundation in algebra and calculus for their future studies and careers.[43]

Recruitment to higher education

All four core subjects of the secondary school curriculum – Chinese Language, English Language, Mathematics and Liberal Studies – are considered mandatory minimum requirements for university entrance.

In general, institutions would consider the application of students who have attained Level 3 for Chinese Language and English Language and Level 2 for Mathematics and Liberal Studies in the HKDSE for admission to four-year undergraduate programmes under the New Academic Structure.

Students who have attained Level 2 or above in five subjects including Chinese Language and English Language are eligible to apply for higher education courses that are below degree level.

Specific entry requirements vary for different tertiary courses and a large number of students also apply to study abroad.[44]

[42] Correspondence with Professor Leung.
[43] Correspondence with Hong Kong's Education Bureau.
[44] Hodgen, J., Pepper, D., Sturman, L., & Ruddock, G. (2010). An international comparison of upper secondary mathematics: 24 Country Profiles: Hong Kong.

Relatively few numerate subjects, including highly numerate disciplines such as engineering, appear to require advanced mathematics for entry to universities in Hong Kong.

Employer recruitment

Students who achieve Level 2 or above in five subjects, including Chinese Language and English Language are eligible to apply for the civil service. These requirements may influence other employers' requirements.

9. What policies and practices are there for transition and retention?

→ What policies or practices are there to support students' transition from lower secondary to upper secondary mathematics options?
→ More generally, what policies or practices are directed at students struggling with upper secondary mathematics?

The Education Development Bureau's (2000) initial proposal for reforming the education system in Hong Kong stated that:

'We would like to see the development of a diversified and multi-channelled system for senior secondary education, which includes different categories of education institutions such
as ordinary schools, senior secondary colleges and vocational training institutes, allowing students to make their choices according to their aptitude and ability' (p.7).[45]

In school education, the Curriculum and Assessment Guide (Secondary 4 – 6) for the Mathematics Education Key Learning Area contains a section focussing on the interface between junior and senior secondary education. It states that: 'To ensure a seamless transition between the junior and senior secondary levels, a coherent curriculum framework is designed for mathematics education at both levels' (p.3). To this end, the same Key Learning Area has the same overall aims at both levels (see Section 2 of this fiche) and the senior secondary curriculum builds on the knowledge, skills, values and attitudes developed at junior secondary level. However, at senior secondary level:

> *A particular learning unit "Inquiry and Investigation" has been included to provide students with opportunities to improve their ability to inquire, communicate, reason and conceptualise mathematical concepts; and there is also a "Further Applications" learning unit in which they have to integrate various parts of mathematics which they have learnt, and thus recognise the inter-relationships between their experiences of concrete objects in junior forms and abstract notions in senior forms.*[46]

In particular, the "Further Applications" learning unit is incorporated into the Compulsory Part to enable students to recognise and appreciate the interconnection between the different parts of mathematics they have learnt at both the junior and senior secondary levels.[47]

The NSSMC notes that: 'Some students in S5 may wish to change the module they selected in S4 (from Module 2 to Module 1 or vice versa) or to study a module they did not intend to

[45] http://www.e-c.edu.hk/eng/reform/annex/Edu-reform-eng.pdf
[46] Page 3 of http://www.edb.gov.hk/FileManager/EN/Content_5999/math_final_e.pdf
[47] http://www.edb.gov.hk/FileManager/EN/Content_5999/math_final_e.pdf

choose at the beginning'. It suggests that: 'To allow for this flexibility, teachers may focus more on the Compulsory Part in S4' (p.94). The NSSMC also notes that: 'In S5, some students may drop the module while others may continue to study it' (p.96).

10. What information is available on (other) factors affecting recruitment and retention?

→ What factors would you attribute to the upper secondary mathematics recruitment levels in your education system?
→ Please give details of any supporting information or sources

In the HKDSE, students take examinations in the core subjects and, usually, two or three optional subjects. This is indicative of the importance attached not just to Chinese and English language but also to mathematics and to broader competences. The relative importance of language is, however, affirmed by higher education entry and employer recruitment requirements. In general, the requirements for entry to higher education degree programmes are higher for Chinese Language and English Language than for Mathematics and Liberal Studies. Sub-degree programmes and civil service entry also place a more explicit emphasis on language than on mathematics. In the HKDSE, students take examinations in the core subjects and, usually, two or three optional subjects. This is indicative of the importance attached not just to Chinese and English language but also to mathematics and to broader competences. The relative importance of language is, however, affirmed by higher education entry and employer recruitment requirements. In general, the requirements for entry to higher education degree programmes are higher for Chinese Language and English Language than for Mathematics and Liberal Studies. Sub-degree programmes and civil service entry also place a more explicit emphasis on language than on mathematics.

As in any system where the subject is compulsory, compulsion might appear to be the decisive factor in ensuring that all upper secondary students in Hong Kong's schools study mathematics. Since few students leave school at lower secondary level, this means that almost all young people of upper secondary age are studying mathematics. Higher education requirements for a minimum level of attainment in mathematics for entry to degree programmes apparently provide a layer of reinforcement for compulsion. These entry requirements are very influential in a socio-cultural context where educational success through highly competitive examinations, including in mathematics, is generally seen as the path to social and economic advancement.

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The changeover from legacy upper secondary school qualifications to the Hong Kong Diploma of Secondary Education (HKDSE) provides further insight. This reform marked a shift from optional mathematics to compulsory mathematics. However, whether following more academic or applied programmes through their wider subject options, there had been few upper secondary school students who did not take mathematics. This indicates that, in practice, there was a strong expectation that upper secondary students would 'choose' to study mathematics. Furthermore, this expectation was effective in ensuring high participation regardless of the optional status of mathematics.

On closer examination it therefore seems that, rather than raising expectations, the new core subject status of mathematics is a product of pre-existing high expectations. Very high numbers of students were already studying mathematics. As a result, Hong Kong's school workforce has made the transition from optional to compulsory mathematics with relative ease. However, importantly, the timescale for implementing the new arrangements made it possible for teachers to train and plan in advance of the implementation of the new curriculum and qualifications.

Information about the reform process also clarifies that there were necessarily limits to what could reasonably be expected of students. A curriculum structure for mathematics based on distinct subject options was rejected because lower recruitment was expected. The implemented structure instead combines a compulsory part and an extended part. One consequence is that a sizeable minority of students sits six hours of examinations covering the compulsory and extended parts. Their results are then reported separately, however, making comparisons more straightforward between students who have, and students who have not, taken the extended part. Students' results are based on terminal, written examinations with multiple choice and open-ended items. Plans for school-based assessment to contribute a broader view of students' mathematical competence to their results have thus far been limited to teachers' day-to-day assessments of their students. The mathematics curriculum emphasises the importance of such assessment for learning and the desirability of using the flexibility in the curriculum to help all students.

Students taking only the compulsory part are expected to spend about 12.5% of timetabled time on mathematics. Students who take the extended part too are expected to progress more quickly, spending 10% of timetabled time on the compulsory part but 5% on the extended part. Rather than being absorbed by other subjects, this additional timetabled time for mathematics results in a longer school day for these students. The additional time and effort required (not to mention the private tutoring that many students receive) means that students must be highly motivated to choose the extended part. However, students' teachers and families both have important roles in filtering students into the different mathematical options. About 20% of students therefore opt into the extended part and they are quite evenly distributed between Module 1 (Calculus and Statistics) for and Module 2 (Calculus and Algebra). These modules are explicitly associated with more (Module 2) or less (Module 1) mathematical career paths. In 2012, on a criterion-referenced scale from Level 1 up to 5**, 50% of students gained at least Level 4 and 75% gained at least Level 3 in the extended part. In summary, student participation in the extended part of the mathematics curriculum appears successful.

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The HKDSE combines more academic and more applied subject options; very few students leave school at the end of lower secondary level to pursue vocational courses. It is therefore important for the associated secondary school curriculum to provide preparation for the full range of career pathways, including through the types of pure and applied mathematical competence students are required to develop.