MATHEMATICS SYLLABUS

Pre-University

Higher 1

Syllabus 8865

Implementation starting with
2020 Pre-University One Cohort

Ministry of Education
SINGAPORE

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1. Introduction

Nature of Mathematics

Mathematics can be described as a study of the *properties*, *relationships*, *operations*, *algorithms*, and *applications* of numbers and spaces at the very basic levels, and of abstract objects and concepts at the more advanced levels. Mathematical objects and concepts, and related knowledge and methods, are products of insight, logical reasoning and creative thinking, and are often inspired by problems that seek solutions. *Abstractions* are what make mathematics a powerful tool for solving problems. Mathematics provides within itself a language for *representing* and *communicating* the ideas and results of the discipline.

Importance of Learning Mathematics

Mathematics contributes to the developments and understanding in many disciplines and provides the foundation for many of today's innovations and tomorrow's solutions. It is used extensively to model and understand real-world phenomena (e.g. consumer preferences, population growth, and disease outbreak), create lifestyle and engineering products (e.g. animated films, mobile games, and autonomous vehicles), improve productivity, decision-making and security (e.g. business analytics, academic research and market survey, encryption, and recognition technologies).

In Singapore, mathematics education plays an important role in equipping every citizen with the necessary knowledge and skills and the capacities to think logically, critically and analytically to participate and strive in the future economy and society. In particular, for future engineers and scientists who are pushing the frontier of technologies, a strong foundation in mathematics is necessary as many of the Smart Nation initiatives that will impact the quality of lives in the future will depend heavily on computational power and mathematical insights.

Mathematics at the A-Level

There are four syllabuses to cater to the different needs, interests, and abilitites of students:

- H1 Mathematics;
- H2 Mathematics;
- H2 Further Mathematics; and
- H3 Mathematics.

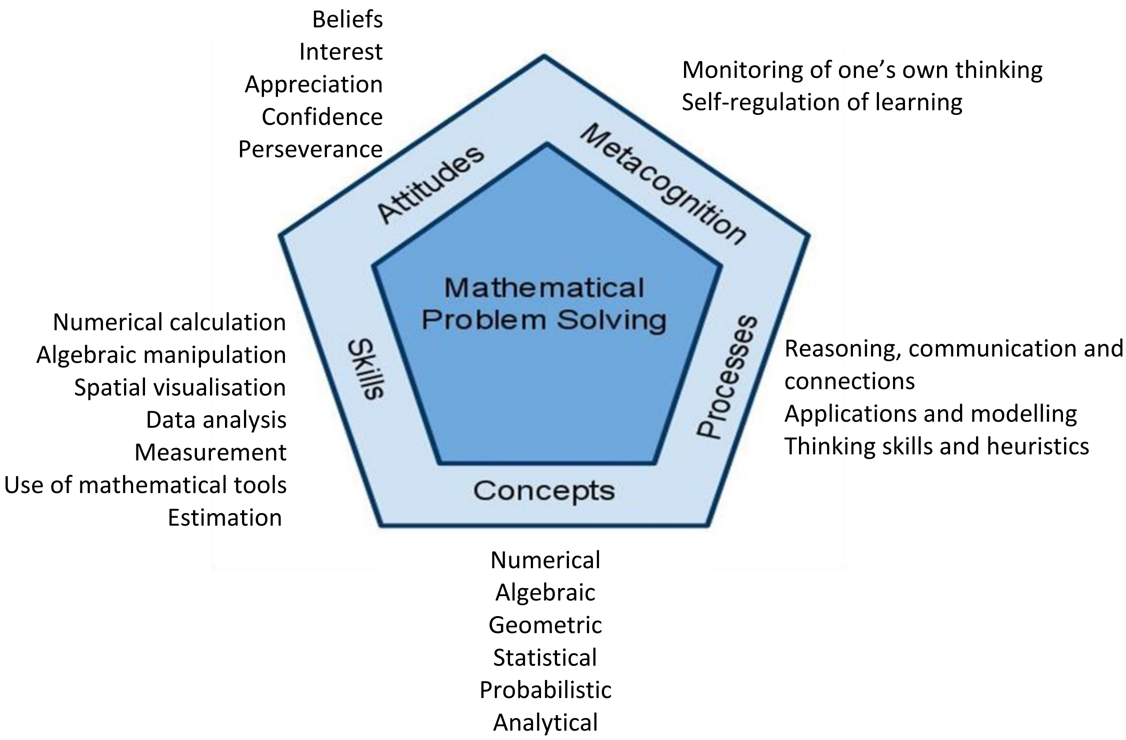
H1 Mathematics is designed to provide students with a foundation in mathematics and statistics that will support their business or social sciences studies at the university. It is particularly appropriate for students without an Additional Mathematics background because it offers an opportunity for them to learn important mathematical concepts and skills in algebra and calculus that are covered in Additional Mathematics. Students will also learn basic statistical methods that are necessary for studies in business and social sciences.

Assumed knowledge: O-Level Mathematics

Learning mathematics at the A-Level provides students, regardless of the intended course of study at the university, with a useful set of tools and problem solving skills. It also exposes students to a way of thinking that complements other ways of thinking developed through the other disciplines.

Mathematics Curriculum Framework

- *Mathematical Problem Solving*



The central focus of the mathematics curriculum is the development of mathematical problem solving competency. Supporting this focus are five inter-related components – concepts, skills, processes, metacognition and attitudes. The framework sets the direction for and provides guidance in the teaching, learning, and assessment of mathematics.

- *Concepts*

Mathematical concepts can be broadly grouped into *numerical*, *algebraic*, *geometric*, *statistical*, *probabilistic*, and *analytical* concepts. These content categories are connected and interdependent. At different stages of learning and in different syllabuses, the breadth and depth of the content vary.

- *Skills*

Mathematical skills refer to *numerical calculation*, *algebraic manipulation*, *spatial visualisation*, *data analysis*, *measurement*, *use of mathematical tools*, and *estimation*. The skills are specific to mathematics and are important in the learning and application of mathematics. In today's classroom, these skills also include the abilities to use spreadsheets and other software to learn and do mathematics.

- *Processes*

Mathematical processes refer to the process skills involved in the process of acquiring and applying mathematical knowledge. These include *reasoning, communication and connections*, *applications and modelling*, and *thinking skills and heuristics* that are important in mathematics.

Reasoning, communication and connections:

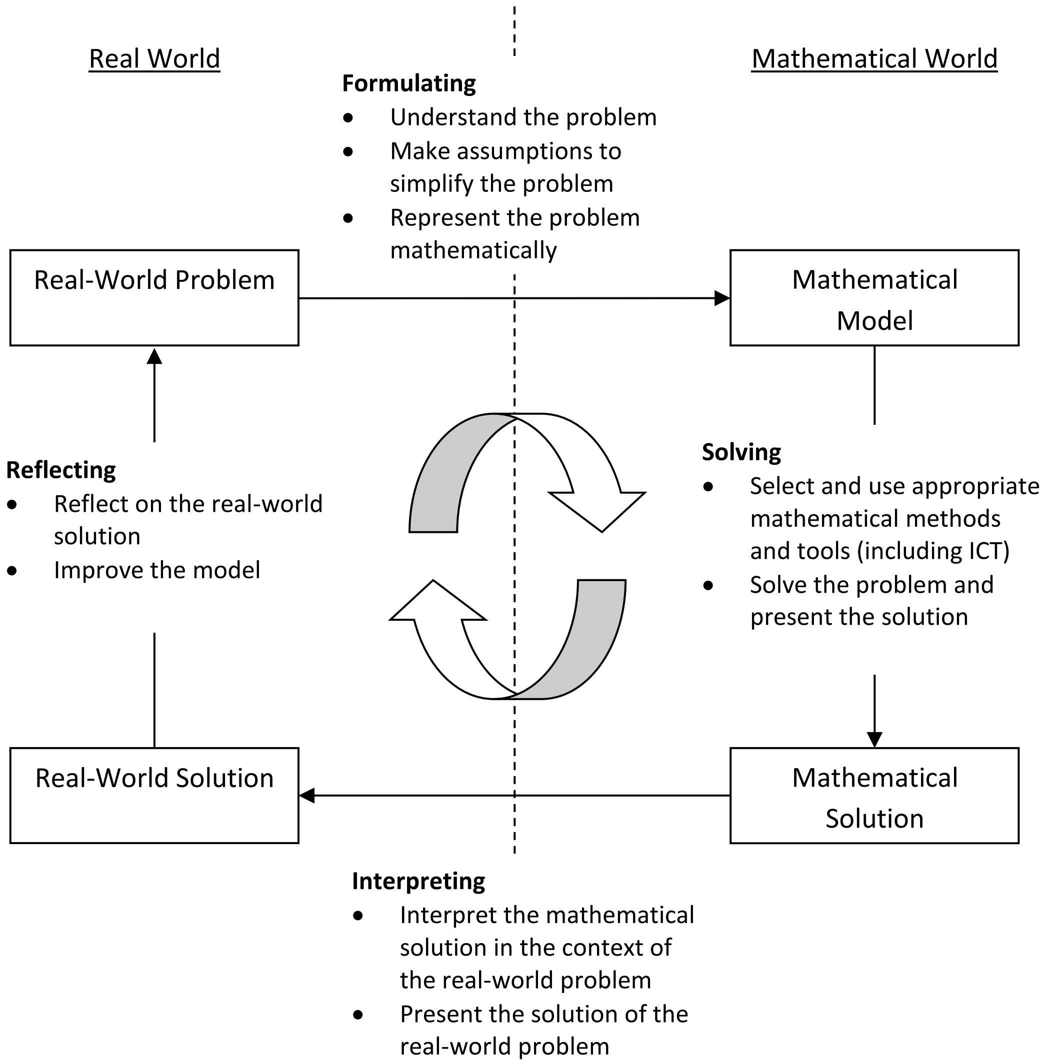
- Mathematical reasoning refers to the ability to analyse mathematical situations and construct logical arguments.
- Communication refers to the ability to use mathematical language to express mathematical ideas and arguments precisely, concisely and logically.
- Connections refer to the ability to see and make linkages among mathematical ideas, between mathematics and other subjects, and between mathematics and the real world.

Applications and modelling allow students to connect mathematics to the real world, enhance understanding of key mathematical concepts and methods, as well as develop mathematical competencies. Mathematical modelling is the process of formulating and improving a mathematical model[1] to represent and solve real-world problems. Through mathematical modelling, students learn to deal with complexity and ambiguity by simplifying and making reasonable assumptions, select and apply appropriate mathematical concepts and skills that are relevant to the problems, and interpret and evaluate the solutions in the context of the real-world problem. [The mathematical modelling process is shown in the diagram on the following page.]

Thinking skills and heuristics are essential for mathematical problem solving. Thinking skills refers to the ability to classify, compare, analyse, identify patterns and relationships, generalise, deduce and visualise. Heuristics are general strategies that students can use to solve non-routine problems. These include using a representation (e.g. drawing a diagram, tabulating), making a guess (e.g. trial and error/ guess and check, making a supposition), walking through the process (e.g. working backwards) and changing the problem (e.g. simplifying the problem, considering special cases).

[1] A mathematical model is a mathematical representation or idealisation of a real-world situation. It can be as complicated as a system of equations or as simple as a geometrical figure. As the word "model" suggests, it shares characteristics of the real-world situation that it seeks to represent.

Mathematical Modelling Process



- *Metacognition*

Metacognition, or thinking about thinking, refers to the awareness of, and the ability to control one's thinking processes, in particular the selection and use of problem-solving strategies. It includes monitoring of one's own thinking, and self-regulation of learning.

- *Attitudes*

Attitudes refer to the affective aspects of mathematics learning such as:

- beliefs about mathematics and its usefulness;
- interest and enjoyment in learning mathematics;
- appreciation of the beauty and power of mathematics;
- confidence in using mathematics; and
- perseverance in solving a problem.

Mathematics and 21CC

Learning of mathematics creates opportunities for students to develop key competencies that are important in the 21st century. As an overarching approach, the A-Level mathematics curriculum supports the development of 21st century competencies (21CC) in the following ways:

1. The content are relevant to the needs of the 21st century. They provide the foundation for learning many of the advanced applications of mathematics that are relevant to today's world.

2. The pedagogies create opportunities for students to think critically, reason logically and communicate effectively, working individually as well as in groups, using ICT tools where appropriate in learning and doing mathematics.

3. The problem contexts raise students' awareness of local and global issues around them. For example, problems set around population issues and health issues can help students understand the challenges faced by Singapore and those around the world.

SECTION 2:
H1 MATHEMATICS SYLLABUS

Preamble
Aims of Syllabus
Content Strands
Applications and Contexts
Content

2. H1 MATHEMATICS SYLLABUS (FROM 2020)

Preamble

The applications of mathematics extend beyond the sciences and engineering domains. A basic understanding of mathematics and statistics, and the ability to think mathematically and statistically are essential for an educated and informed citizenry. For example, social scientists use mathematics to analyse data, support decision making, model behaviour, and study social phenomena.

H1 Mathematics provides students with a foundation in mathematics and statistics that will support their business or social sciences studies at the university. It is particularly appropriate for students without O-Level Additional Mathematics background because it offers an opportunity for them to learn important mathematical concepts and skills in algebra and calculus that were taught in Additional Mathematics. Students will also learn basic statistical methods that are necessary for studies in business and social sciences.

Syllabus Aims

The aims of H1 Mathematics are to enable students to:

(a) acquire mathematical concepts and skills to support their tertiary studies in business and the social sciences;
(b) develop thinking, reasoning, communication and modelling skills through a mathematical approach to problem-solving;
(c) connect ideas within mathematics and apply mathematics in the context of business and social sciences; and
(d) experience and appreciate the value of mathematics in life and other disciplines.

Content Strands

There are 3 content strands in H1 Mathematics, namely, *Functions and Graphs*, *Calculus*, and *Probability and Statistics*.

a) <u>Functions and Graphs</u> provides the foundation for algebraic and quantitative reasoning and includes useful topics such as exponential and logarithmic functions, graphing techniques and tools (e.g. graphing calculators), techniques for solving equations, inequalities and system of equations.

b) <u>Calculus</u> provides useful tools for analysing and modelling change and behaviour, and includes basic differentiation and integration concepts, techniques and applications such as finding optimal value and area under a curve.

c) Probability and Statistics provides the foundation for modelling chance phenomena and making inferences with data and includes an introduction to counting techniques, computation of probability, binomial and normal distributions, sampling and hypothesis testing as well as correlation and regression.

There are many connections that can be made between the topics within each strand and across strands, even though the syllabus content are organised in strands. These connections should be emphasised as part of teaching and learning, to enable students to integrate the concepts and skills in a coherent manner to solve problems.

Knowledge of the content of O-Level Mathematics syllabus is assumed in this syllabus.

Applications and Contexts

As H1 Mathematics is designed for students who intend to pursue further studies in business and social sciences courses, students should therefore be exposed to the applications of mathematics in business and social sciences, so that they can appreciate the value and utility of mathematics in these likely courses of study.

The list illustrates the kinds of contexts that the mathematics learnt in the syllabus may be applied, and is by no means exhaustive.

Applications and contexts	**Some possible topics involved**
Optimisation problems (e.g. maximising profits, minimising costs)	Inequalities; System of linear equations; Calculus
Population growth, radioactive decay	Exponential and logarithmic functions
Financial Maths (e.g. profit and cost analysis, demand and supply, banking, insurance)	Equations and inequalities; Probability; Sampling distributions; Correlation and regression
Games of chance, elections	Probability
Standardised testing	Normal distribution; Probability
Market research (e.g. consumer preferences, product claims)	Sampling distributions; Hypothesis testing; Correlation and regression
Clinical research (e.g. correlation studies)	Sampling distributions; Hypothesis testing; Correlation and regression

While students will be exposed to applications and contexts beyond mathematics, they are not expected to learn them in depth. Students should be able to use given information to formulate and solve the problems, applying the relevant concepts and skills and interpret the solution in the context of the problem.

Content

	Topics/ Sub-topics	Content
SECTION A: PURE MATHEMATICS		
1	**Functions and Graphs**	
1.1	Exponential and logarithmic functions and Graphing techniques	Include: • concept of function as a rule or relationship where for every input there is only one output • use of notations such as $\mathrm{f}(x)=x^2+5$ • functions e^x and $\ln x$ and their graphs • exponential growth and decay • logarithmic growth • equivalence of $y=\mathrm{e}^x$ and $x=\ln y$ • laws of logarithms • use of a graphing calculator to graph a given function • characteristics of graphs such as symmetry, intersections with the axes, turning points and asymptotes (horizontal and vertical) Exclude: • use of the terms domain and range • use of notation $\mathrm{f}: x \mapsto x^2+5$ • change of base of logarithms
1.2	Equations and inequalities	Include: • conditions for a quadratic equation to have (i) two real roots, (ii) two equal roots, and (iii) no real roots • conditions for ax^2+bx+c to be always positive (or always negative) • solving simultaneous equations, one linear and one quadratic, by substitution • solving quadratic equations and inequalities in one unknown analytically • solving inequalities by graphical methods • formulating an equation or a system of linear equations from a problem situation • finding the approximate solution of an equation or a system of linear equations using a graphing calculator

	Topics/ Sub-topics	Content
2	**Calculus**	
2.1	Differentiation	Include: • derivative of $f(x)$ as the gradient of the tangent to the graph of $y = f(x)$ at a point • use of standard notations $f'(x)$ and $\frac{dy}{dx}$ • derivatives of x^n for any rational n, e^x, $\ln x$, together with constant multiples, sums and differences • use of chain rule • graphical interpretation of $f'(x) > 0$, $f'(x) = 0$ and $f'(x) < 0$ • use of the first derivative test to determine the nature of the stationary points (local maximum and minimum points and points of inflexion) in simple cases • locating maximum and minimum points using a graphing calculator • finding the approximate value of a derivative at a given point using a graphing calculator • finding equations of tangents to curves • local maxima and minima problems • connected rates of change problems Exclude: • differentiation from first principles • derivatives of products and quotients of functions • use of $\frac{dy}{dx} = \frac{1}{\frac{dx}{dy}}$ • differentiation of functions defined implicitly or parametrically • finding non-stationary points of inflexion • relating the graph of $y = f'(x)$ to the graph of $y = f(x)$
2.2	Integration	Include: • integration as the reverse of differentiation • integration of x^n for any rational n, and e^x, together with constant multiples, sums and differences • integration of $(ax+b)^n$ for any rational n, and $e^{(ax+b)}$ • definite integral as the area under a curve • evaluation of definite integrals • finding the area of a region bounded by a curve and lines parallel to the coordinate axes, between a curve and a line, or between two curves • finding the approximate value of a definite integral using a graphing calculator Exclude: • definite integral as a limit of sum • approximation of area under a curve using the

	Topics/ Sub-topics	Content
		trapezium rule • area below the *x*-axis
SECTION B: PROBABILITY AND STATISTICS		
3	**Probability and Statistics**	
3.1	Probability	Include: • addition and multiplication principles for counting • concepts of permutation ($^{n}P_{r}$) and combination ($^{n}C_{r}$) • arrangements of distinct objects in a line including cases involving restriction • addition and multiplication of probabilities • mutually exclusive events and independent events • use of tables of outcomes, Venn diagrams, tree diagrams, and permutations and combinations techniques to calculate probabilities • calculation of conditional probabilities in simple cases • use of: $\text{P}(A')=1-\text{P}(A)$ $\text{P}(A\cup B)=\text{P}(A)+\text{P}(B)-\text{P}(A\cap B)$ $\text{P}(A\mid B)=\dfrac{\text{P}(A\cap B)}{\text{P}(B)}$
3.2	Binomial distribution	Include: • knowledge of the binomial expansion of $(a+b)^n$ for positive integer *n* • binomial random variable as an example of a discrete random variable • concept of binomial distribution $\text{B}(n,p)$ and use of $\text{B}(n,p)$ as a probability model, including conditions under which the binomial distribution is a suitable model • use of mean and variance of a binomial distribution (without proof)
3.3	Normal distribution	Include: • concept of a normal distribution as an example of a continuous probability model and its mean and variance; use of $\text{N}(\mu,\sigma^2)$ as a probability model • standard normal distribution • finding the value of $\text{P}(X < x_1)$ or a related probability given the values of x_1,μ,σ • symmetry of the normal curve and its properties • finding a relationship between x_1,μ,σ given the value of $\text{P}(X < x_1)$ or a related probability • solving problems involving the use of $\text{E}(aX+b)$ and $\text{Var}(aX+b)$

	Topics/ Sub-topics	Content
		• solving problems involving the use of $\mathrm{E}(aX+bY)$ and $\mathrm{Var}(aX+bY)$, where X and Y are independent Exclude normal approximation to binomial distribution.
3.4	Sampling	Include: • concepts of population and simple random sample • concept of the sample mean $\overline{X}$ as a random variable with $\mathrm{E}(\overline{X})=\mu$ and $\mathrm{Var}(\overline{X})=\frac{\sigma^2}{n}$ • distribution of sample mean from a normal population • use of the Central Limit Theorem to treat sample mean as having normal distribution when the sample size is sufficiently large (e.g. $n \geq 30$) • calculation of unbiased estimates of the population mean and variance from a sample, including cases where the data are given in summarised form $\sum x$ and $\sum x^2$, or $\sum(x-a)$ and $\sum(x-a)^2$
3.5	Hypothesis testing	Include: • concepts of null hypothesis (H_0) and alternative hypotheses (H_1), test statistic, critical region, critical value, level of significance and p-value • formulation of hypotheses and testing for a population mean based on: - a sample from a normal population of known variance - a large sample from any population • 1-tail and 2-tail tests • interpretation of the results of a hypothesis test in the context of the problem Exclude the use of the term 'Type I error', concept of Type II error and testing the difference between two population means.

	Topics/ Sub-topics	Content
3.6	Correlation and Linear regression	Include: • use of scatter diagram to determine if there is a plausible linear relationship between the two variables • correlation coefficient as a measure of the fit of a linear model to the scatter diagram • finding and interpreting the product moment correlation coefficient (in particular, values close to -1, 0 and 1) • concepts of linear regression and method of least squares to find the equation of the regression line • concepts of interpolation and extrapolation • use of the appropriate regression line to make prediction or estimate a value in practical situations, including explaining how well the situation is modelled by the linear regression model Exclude: • derivation of formulae • relationship $r^2 = b_1 b_2$, where b_1 and b_2 are regression coefficients • hypothesis tests • use of a square, reciprocal or logarithmic transformation to achieve linearity

SECTION 3:
PEDAGOGY AND
FORMATIVE ASSESSMENT

Teaching Processes
Phases of Learning
Formative Assessment
Use of Technology

3. PEDAGOGY AND FORMATIVE ASSESSMENT

Teaching Processes

The Pedagogical Practices of The Singapore Teaching Practice (STP) outlines four Teaching Processes that make explicit what teachers reflect on and put into practice before, during and after their interaction with students in all learning contexts.

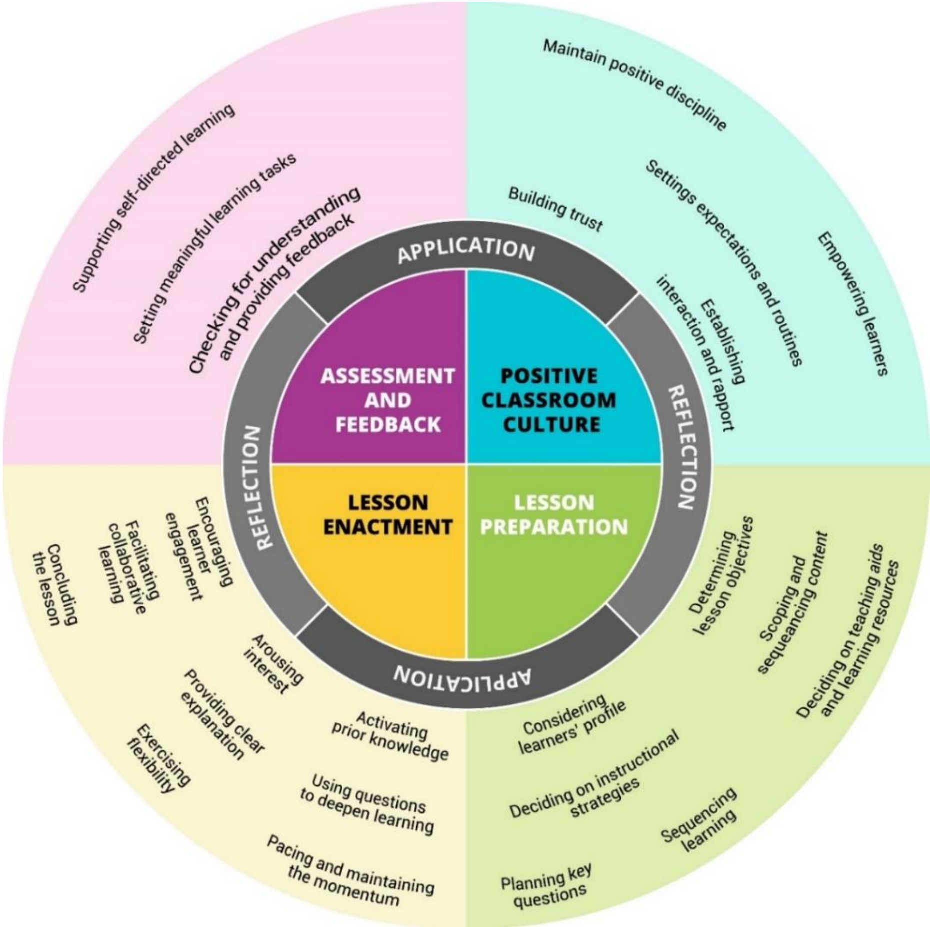
It is important to view the Pedagogical Practices of the STP in the context of the Singapore Curriculum Philosophy (SCP) and Knowledge Bases (KB), and also to understand how all three components work together to support effective teaching and learning.

Taking reference from the SCP, every student is valued as an individual, and they have diverse learning needs and bring with them a wide range of experiences, beliefs, knowledge, and skills. For learning to be effective, there is a need to adapt and match the teaching pace, approaches and assessment practices so that they are developmentally appropriate.

The 4 Teaching Processes are further expanded into Teaching Areas as follows:

Assessment and Feedback • Checking for Understanding and Providing Feedback • Supporting Self-Directed Learning • Setting Meaningful Assignments	Positive Classroom Culture • Establishing Interaction and Rapport • Maintaining Positive Discipline • Setting Expectations and Routines • Building Trust • Empowering Learners
Lesson Enactment • Activating Prior Knowledge • Arousing Interest • Encouraging Learner Engagement • Exercising Flexibility • Providing Clear Explanation • Pacing and Maintaining Momentum • Facilitating Collaborative Learning • Using Questions to Deepen Learning • Concluding the Lesson	Lesson Preparation • Determining Lesson Objectives • Considering Learners' Profile • Selecting and Sequencing Content • Planning Key Questions • Sequencing Learning • Deciding on Instructional Strategies • Deciding on Teaching Aids and Learning Resources

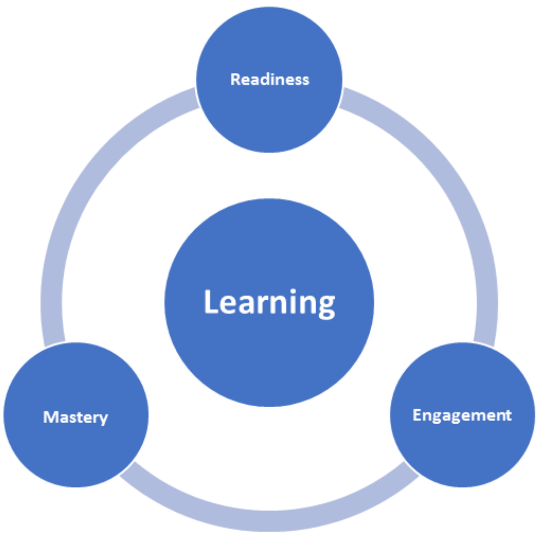
The Teaching Areas are not necessarily specific to a single Teaching Process. Depending on the context, some of the Teaching Areas could be considered in another Teaching Process. The Teaching Processes are undergirded by a constant cycle of application and reflection.



For more information on STP, go to https://www.moe.gov.sg/about/singapore-teaching-practice

Phases of Learning

The Teaching Areas in STP are evident in the effective planning and delivery of the three phases of learning - *readiness*, *engagement* and *mastery*.



Readiness Phase

Student readiness to learn is vital to learning success. Teachers have to consider the following:

- Learning environment
- Students' profile
- Students' prior and pre-requisite knowledge
- Motivating contexts

Engagement Phase

This is the main phase of learning where students engage with the new materials to be learnt (*Encouraging Learner Engagement*). As students have diverse learning needs and bring with them a wide range of experiences, beliefs, knowledge and skills, it is important to consider the pace of the learning and transitions (*Pacing and Maintaining Momentum*) using a repertoire of pedagogies.

Three pedagogical approaches form the spine that supports most of the mathematics instruction in the classroom. They are not mutually exclusive and could be used in different parts of a lesson or unit. Teachers make deliberate choices on the instructional strategies (Deciding on Instructional Strategies) based on learners' profiles and needs, and the nature of the concepts to be taught. The engagement phase can include one or more of the following:

- Activity-based Learning
- Inquiry-based Learning
- Direct Instruction

Regardless of the approach, it is important for teachers to plan ahead, anticipate students' responses, and adapt the lesson accordingly (Exercising Flexibility).

Mastery Phase

The mastery phase is the final phase of learning where students consolidate and extend their learning. To consolidate, teachers summarise and review key learning points at the end of a lesson and make connections with the subsequent lesson (Concluding the Lesson). The mastery phase can include one or more of the following:

- Motivated Practice
- Reflective Review
- Extended Learning

Formative Assessment

Assessment is an integral part of the teaching and learning. It can be formative or summative or both. Formative assessment or Assessment for Learning (AfL) is carried out during teaching and learning to gather evidence and information about students' learning.

The *purpose* of formative assessment is to help students improve their learning and be self-directed in their learning. In learning of mathematics, just as in other subjects, information about students' understanding of the content must be gathered *before*, *during* and *after* the lesson.

The outcomes of the mathematics curriculum go beyond just the recall of mathematical concepts and skills. Since mathematical problem solving is the focus of the mathematics curriculum, assessment should also focus on students' understanding and ability to apply what they know to solve problems. In addition, there should be emphasis on processes such as reasoning, communicating, and modelling.

The overarching objectives of assessment should focus on students':

- understanding of mathematical concepts (going beyond simple recall of facts);
- ability to reason, communicate, and make meaningful connections and integrate ideas across topics;
- ability to formulate, represent and solve problems within mathematics and to interpret mathematical solutions in the context of the problems; and
- ability to develop strategies to solve non-routine problems.

The process of assessment is embedded in the planning of the lessons. The embedding of assessment process may take the following forms:

- Class Activities
- Classroom Discourse
- Individual or Group Tasks

Assessment provides feedback for both students and teachers.

- Feedback from teachers to students informs students where they are in their learning and what they need to do to improve their learning.
- Feedback from students to teachers comes from their responses to the assessment tasks designed by teachers. They provide information to teachers on what they need to do to address learning gaps, how to modify the learning activities students engage in, and how they should improve their instruction.
- Feedback between students is important as well because peer-assessment is useful in promoting active learning. It provides an opportunity for students to learn from each other and also allows them to develop an understanding of what counts as quality work by critiquing their peers' work in relation to a particular learning outcome.

Use of Technology

Computational tools are essential in many branches of mathematics. They support the discovery of mathematical results and applications of mathematics. Mathematicians use computers to solve computationally challenging problems, explore new ideas, form conjectures and prove theorems. Many of the applications of mathematics rely on the availability of computing power to perform operations at high speed and on a large scale. Therefore, integrating technology into the learning of mathematics gives students a glimpse of the tools and practices of mathematicians.

Computational tools are also essential for the learning of mathematics. In particular, they support the understanding of concepts (e.g. simulation and digital manipulatives), their properties (e.g. geometrical properties) and relationships (e.g. algebraic form versus graphical form). More generally, they can be used to carry out investigation (e.g. dynamic geometry software, graphing tools and spreadsheets), communicate ideas (e.g. presentation tools) and collaborate with one another as part of the knowledge building process (e.g. discussion forum). Getting students who have experience with coding to implement some of the algorithms in mathematics (e.g. finding prime factors, multiplying two matrices) can potentially help these students develop a clearer understanding of the algorithms and the underlying mathematics concepts as well.

SECTION 4:
SUMMATIVE ASSESSMENT

Purpose and Assessment Objectives
National Examination (Syllabus 8865)

4. SUMMATIVE ASSESSMENT

Purpose and Assessment Objectives

The purpose of summative assessments, such as tests and examinations, is to measure the extent to which students have achieved the learning objectives of the syllabuses.

The assessment objectives reflect the emphases of the syllabus and describe what students should know and be able to do with the concepts and skills learned.

National Examination: H1 Mathematics (Syllabus 8865)

Important information on the national examination for H1 Mathematics is highlighted below. Full details are available on the SEAB website.

The examination will be based on the topics/content listed in Section 2. Knowledge of O-Level Mathematics is assumed.

The use of an approved graphing calculator will be expected.

ASSESSMENT OBJECTIVES (AO)
There are three levels of assessment objectives for the examination.

The assessment will test candidates' abilities to:

AO1 Understand and apply mathematical concepts and skills in a variety of problems, including those that may be set in unfamiliar contexts, or require integration of concepts and skills from more than one topic.

AO2 Formulate real-world problems mathematically, solve the mathematical problems, interpret and evaluate the mathematical solutions in the context of the problems.

AO3 Reason and communicate mathematically through making deductions and writing mathematical explanations and arguments.

Notwithstanding the presentation of the topics in the syllabus document, it is envisaged that some examination questions may integrate ideas from more than one topic, and that topics may be tested in the contexts of problem solving and application of mathematics. While problems may be set in context, no assumptions will be made about the knowledge of the context. All information will be self-contained within the problem.

SCHEME OF EXAMINATION PAPERS

For the examination in H1 Mathematics, there will be one 3-hour paper marked out of 100 as follows:

Section A (Pure Mathematics – 40 marks) will consist of about 5 questions of different lengths and marks based on the Pure Mathematics section of the syllabus.

Section B (Probability and Statistics – 60 marks) will consist of 6 to 8 questions of different lengths and marks based on the Probability and Statistics section of the syllabus.

There will be at least two questions, with at least one in each section, on application of Mathematics in real-world contexts, including those from business and the social sciences. Each question will carry at least 12 marks and may require concepts and skills from more than one topic.

Candidates will be expected to answer all questions.