DP Country Alignment Studies: Alignment of the Singaporean GCE A Level (SGA)

Submitted by Ecctis to the IB

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Ecctis

Acronyms

21CC	21st century competencies
AA	mathematics: analysis and approaches
AHL	additional higher level
AI	mathematics: applications and interpretation
ATL	approaches to teaching and learning
CP	Career-related Programme
CAS	creativity, activity, service
DP	Diploma Programme
GCE	General Certificate of Education
GP	general paper
HL	higher level
H2F	Higher 2 further (mathematics)
IB	International Baccalaureate
IBO	International Baccalaureate Organisation
ITE	Institute of Technical Education
JC	junior colleges
KI	knowledge and inquiry
MCF	mathematics curriculum framework
MI	millennia institute
MOE	Ministry of Education
MTL	mother tongue language
MYP	Middle Years Programme
PYP	Primary Years Programme
RfP	Request for Proposal

RQ	research question
SEAB	Singapore Examinations and Assessment Board
SGA	Singaporean GCE A Level
SL	standard level
TOK	theory of knowledge
USA	United States of America
WIAIBE	What is an IB education?

Contents

1. Executive Summary

Project Aims and Context

The International Baccalaureate (IB) Organization is a not-for-profit educational foundation offering four programmes across the world. One of them – the Diploma Programme (DP) – is a two-year upper secondary programme, primarily intended to prepare students for university matriculation and higher education.

Ecctis was commissioned by the IB to deliver a series of in-depth studies to assess the level of alignment between the DP and comparison points within the upper secondary education systems of Australia, Canada, the USA (United States of America), Singapore, South Korea, and Finland. More specifically, the studies aim to identify areas of similarities and differences between the DP and these educational systems to inform the IB's development of tools and resources for IB teachers, ultimately helping them navigate between the DP and the local curriculum in the target countries. In doing so, the studies also contribute to further supporting fair recognition of the DP by institutions, employers, and other key stakeholders, supporting progression and mobility for DP holders. The studies include, for all countries, a focus on mathematics and the sciences, with an additional focus on history for Australia, and English for the USA.

This report aims to specifically evaluate alignment between the DP and the upper-secondary programme of education in Singapore. The comparison programme in question is the Singaporean GCE A Level (SGA).

Research Questions and Methods

All comparative studies in this series have been framed by responses to Research Questions (RQs), both at programme and subject levels. For this study, these RQs were the following:

RQ1: To what degree does the DP curriculum align with the Singaporean upper secondary curriculum? In what way are the curricula similar and in what way are they different in demand and difficulty? To what degree are the curricula compatible?

RQ2: To what degree do the curricula align with regard to their:

2.1: Philosophical underpinnings
- Objectives
- Principles
- Values.

2.2: Structure
- Learning areas
- Subject offerings
- Degree of specialization
- Time allocation.

2.3: Requirements
- Programme entry requirements
- Time requirements (i.e. programme duration, teaching hours, study hours)
- Certificate requirements (i.e. credits, passing and failing conditions, compensation options).

2.4: Assessment

- Nature of assessment (i.e. number, type, duration, question types, availability of marks)
- Assessment model (i.e. relative weighting of assessments to overall grades).

2.5: Student learning pathways

- Degree of specialization
- Options in subject (area) choice (i.e. compulsory subjects, electives).

RQ3: To what degree do the subjects align with regard to:

3.1: Content

- Topics (i.e. scope of content area, breadth, depth)
- Learning activities (i.e. difficulty, demand).

3.2: Expected learning outcomes

- Knowledge
- Competencies (i.e. subject-specific, 21st century competencies).

To answer the above RQs, Ecctis developed and applied a bespoke methodology.

At programme-level, this involved the comparative analysis of key components of the DP and the SGA, including: philosophical underpinnings, structure, requirements and associated outcomes, student learning pathways, and assessment methods (where possible). At subject-level, it involved the comparative analysis of key components of the DP and SGA subjects, including: learning outcomes, content, and demand.

Where appropriate, Ecctis complemented its standard comparative methodology with a comprehensive mapping method, extracting themes from the DP to evaluate their presence in the comparison point(s). Additionally, to assess demand at subject level, Ecctis designed and deployed an expert panel approach, scoring each individual subject against a common set of demand criteria.[1]

Key Findings

Programme-level

The entry requirements of the two programmes and the student learning pathways are the most significant points of difference and the philosophical underpinnings and assessment methods are the most significant points of similarity. In respect to programme structures, there are some notable differences, though with points of clear alignment with regard to how students would be likely to experience the programmes in practice. Key similarities and differences include:

- **Philosophical underpinnings**: significant overlap was found between the SGA's and DP's philosophical underpinnings, with both being community-oriented and guided by ethical principles; both promoting multiculturalism and diversity, as well as collaborative competence; and both prioritising independent learning, conceptual understanding and higher-order thinking. Notably, the SGA has a more national focus

[1] Each individual subject was scored for: cognitive skills evidenced in the learning outcomes (based on the Revised Bloom's Taxonomy), depth of knowledge (adapted from Webb's Depth of Knowledge levels), volume of work (a tri-factor score considering breadth, depth and allocated timeframe), and outstanding areas of subject demand (stretch areas).

in its approach, placing importance on students' contributions towards Singaporean society, while the DP has a global focus by nature.

- **Programme structure**: both programmes share a similar range of disciplines in languages, humanities, the arts, mathematics and sciences; both offer compulsory skills-based components aimed at promoting holistic development; both offer students the option to study most subjects at different levels; and both encourage some breadth of study – though the DP places greater emphasis on this. Additionally, the two programmes may also be similar in terms of duration, although this depends on the type of educational institution SGA students go to – if studying at a junior college, their programme will be completed in two years, the same duration as the DP. However, if studying at the millennia institute, the SGA programme will last three years instead.

- **Entry requirements**: both programmes present somewhat flexible approaches to entry requirements at the start of their programmes. The IB encourages students and teachers to consult subject guides around expected prior learning but does not provide fixed entry requirements. There are also different pathways which can lead to taking the SGA. Students may study O Levels at the end of their secondary education or be on an Integrated Programme that spans both secondary and pre-university education without requiring O Level examinations.[2] Schools such as junior colleges and the millennia institute set out additional formal entry requirements in the form of admissions criteria.

- **Student learning pathways**: both programmes provide a significant level of optionality in relation to subjects studied; both require students to study subjects from different subject groups; and both provide opportunities for students to expand learning in specific subjects of interest, allowing up to four subjects to be studied at a higher level. Overall, it is possible for SGA students to take a pathway that is very similar to the DP, studying a similar breadth and depth of subjects. The key difference between the two programmes' learning pathways is that, depending on students' choices, pathways can be more specialised in the SGA than the DP. The reason for this is that, unlike the DP, the SGA does not require students to study one subject from each subject group. Thus, SGA students may choose to specialise in one broad area (e.g. the sciences, humanities, or languages) by studying up to four subjects from that area, an option that is not available in the DP. This being said, the DP does offer a non-regular diploma pathway to some students, allowing them to study three sciences and achieve a similar degree of specialisation as that permitted in the SGA.

- **Assessment methods**: the DP and SGA share similar approaches to assessment. Both programmes use external assessment as the main mode of assessment, with a similar approach to assessment duration; both deploy multiple formats of assessment (i.e. written, oral, performance, or in electronic format); and both use similar question types (i.e. short response, extended response, multiple choice, real-world contexts, and experiment-based questions). In both, optionality is rarely used, though does appear in some papers. The main difference between the two programmes is that the DP has internally assessed components in its subjects and the SGA does not.

[2] MOE, Singapore. (2022). *Post-secondary Education Booklet*.

Subject-level

In this study, Ecctis carried out subject-level comparative analysis between the DP and the SGA in mathematics, physics, chemistry and biology, focusing on the following DP standard level (SL) and higher level (HL) subjects, and comparison subjects:

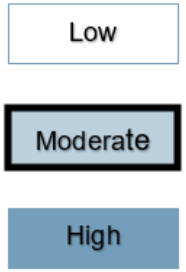
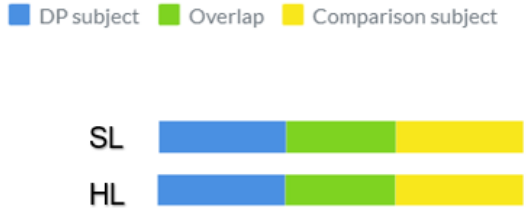
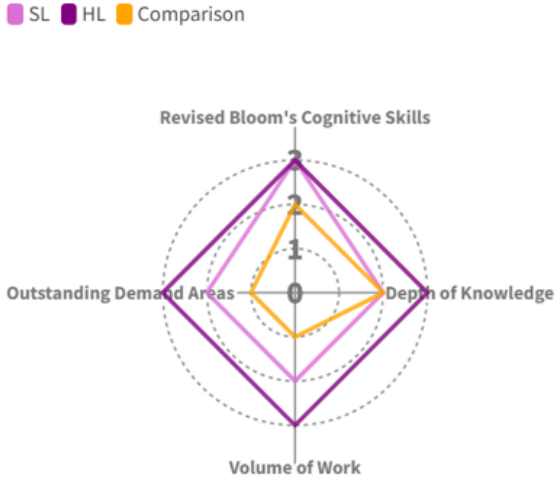
Table: Subject areas for comparison of the DP and the SGA curricula

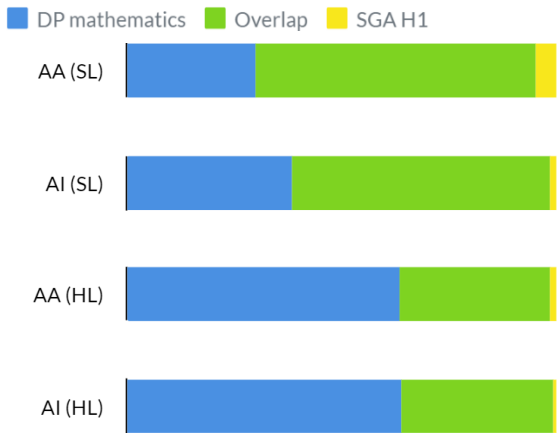
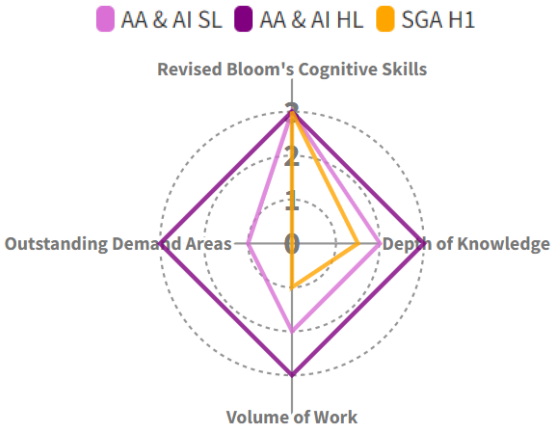
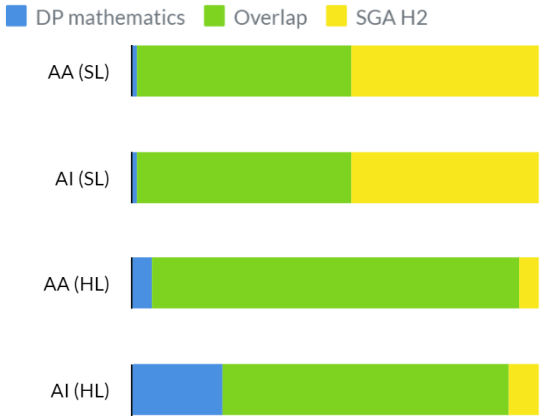
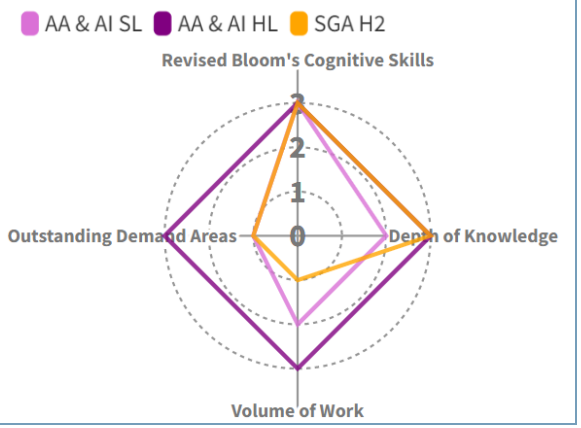
DP subject (group)	Singapore subjects
SCIENCES	
physics SL and HL	Higher 1 (H1) physics Higher 2 (H2) physics Higher 3 (H3) physics
chemistry SL and HL	Higher 1 (H1) chemistry Higher 2 (H2) chemistry Higher 3 (H3) chemistry
biology SL and HL	Higher 1 (H1) biology Higher 2 (H2) biology Higher 3 (H3) biology
MATHEMATICS	
mathematics: analysis and approaches (AA) SL and HL	Higher 1 (H1) mathematics Higher 2 (H2) mathematics Higher 2 further (H2F) mathematics Higher 3 (H3) mathematics
mathematics: applications and interpretation (AI) SL and HL	

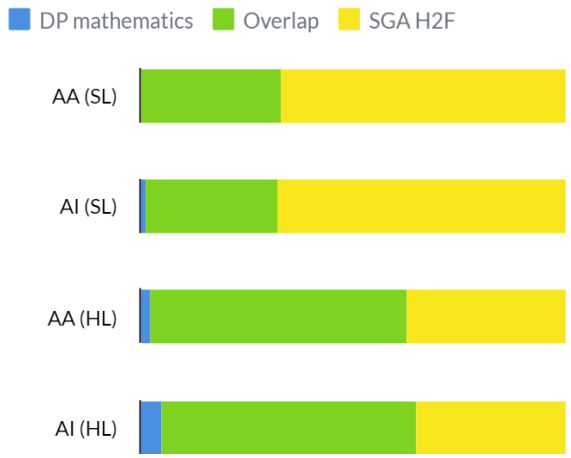
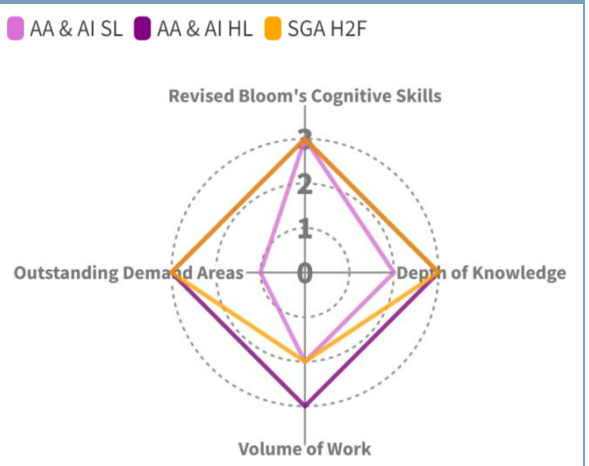
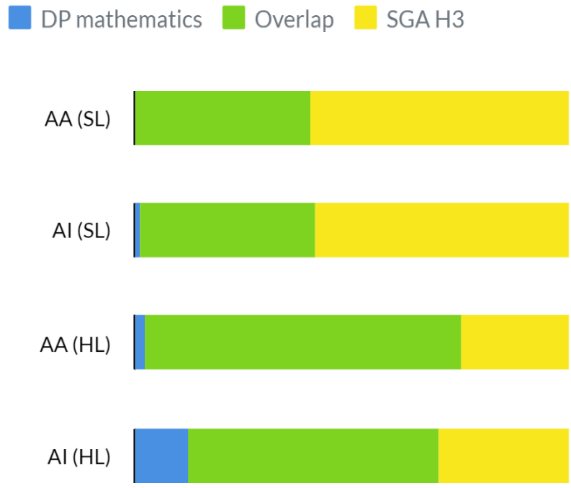
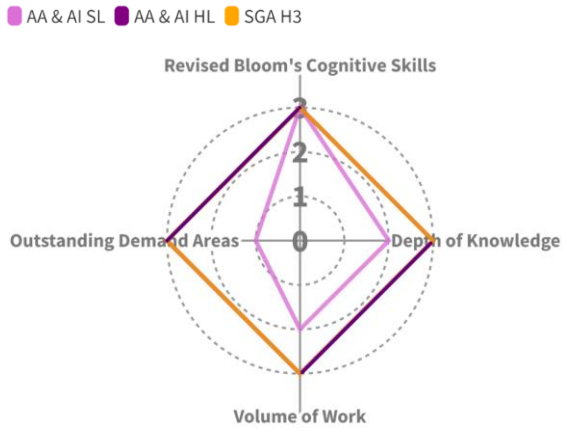
The findings from the subject-level analysis are summarised in the tables below:

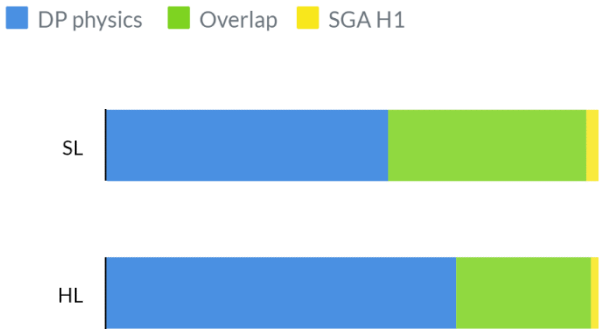
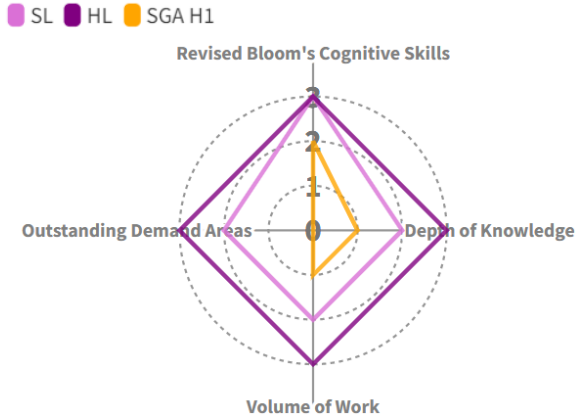
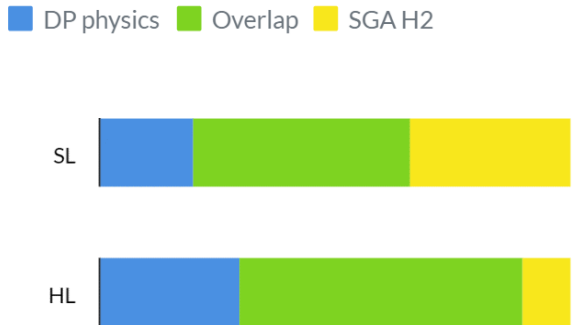
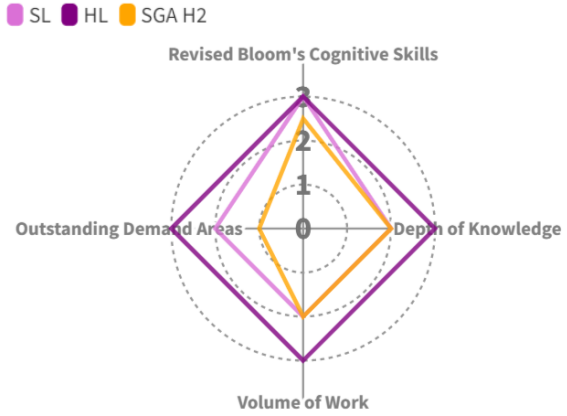
Figures: Visual representation of alignment between DP subjects and comparison subjects

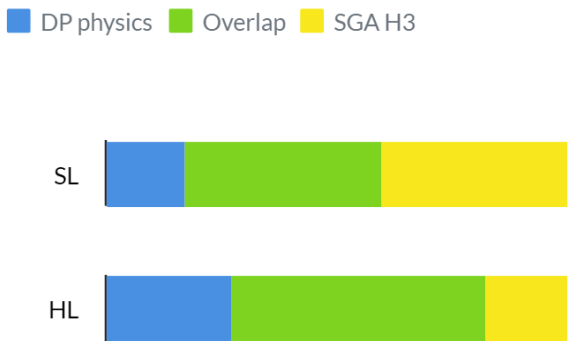
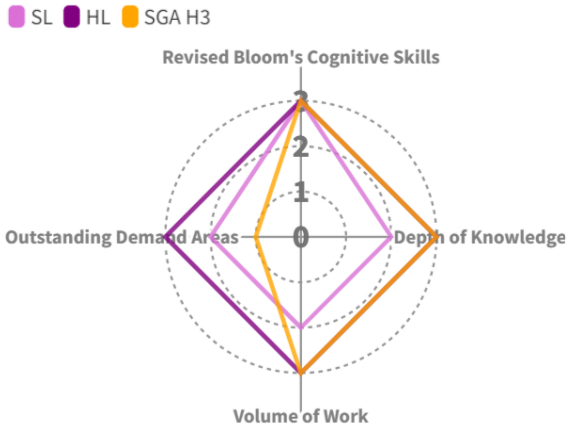
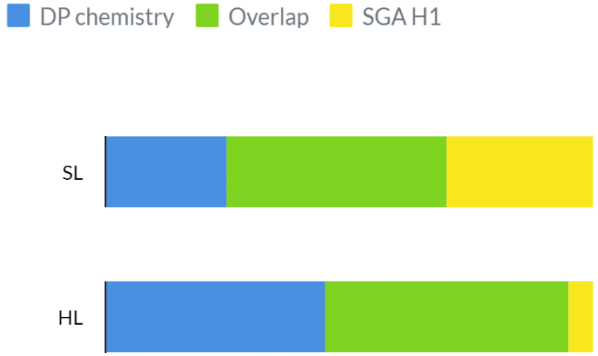
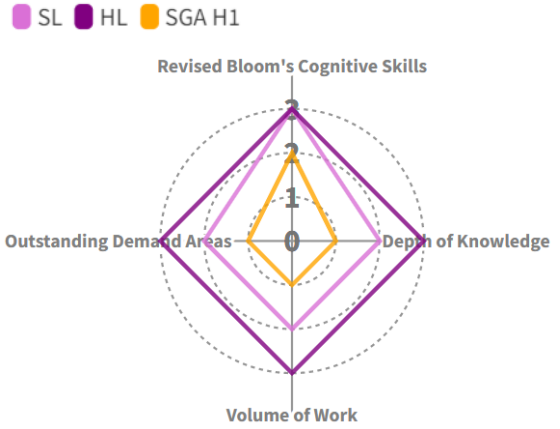
Key:

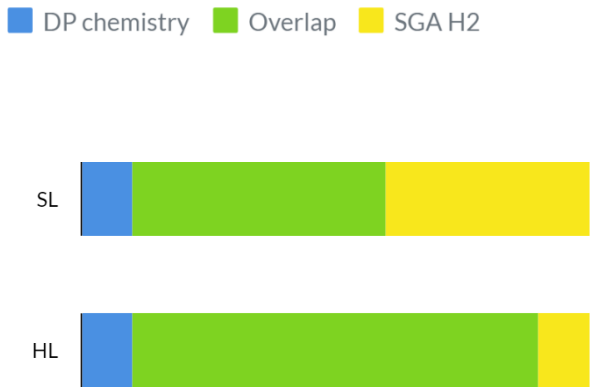
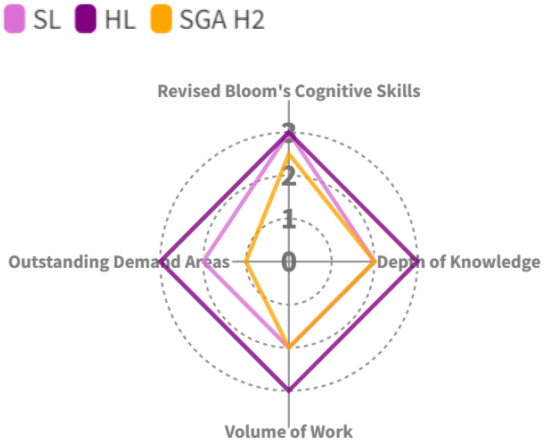
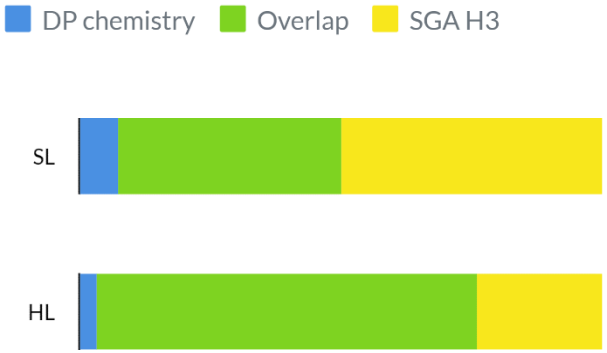
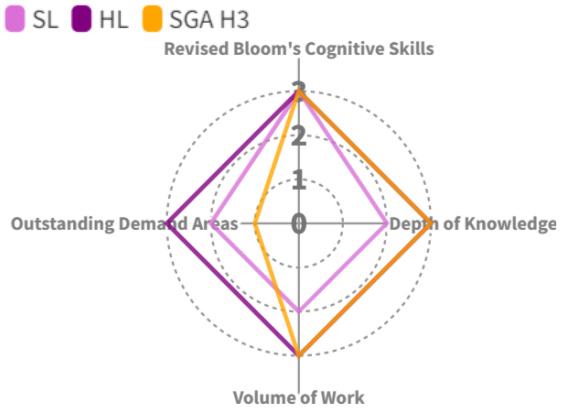
Subject name	Learning outcomes alignment	Content alignment	Demand alignment
Displays the name of the comparison subject	 This represents the learning outcome alignment between the DP subject and the comparison subject. A black border is placed around the selected judgement – 'Moderate' in this example.	 These bars represent the content alignment between the DP subject and the comparison. There is one bar showing alignment with SL content and another for HL content (inclusive of SL content). The **green** section of the bar represents the overlap of content between the subjects. The **blue** section represents content which was in the DP subject only. The **yellow** section represents content which was in the comparison subject only. Therefore, if, say, the blue section was longer than the yellow, this can be interpreted as the DP subject having more content unique to itself than the comparison did. A large green bar would indicate that a substantial proportion of content is common to both the DP and comparison subject.	 This radar diagram displays the demand judgement scores for the comparison subject(s) and the DP subject – both SL and HL.

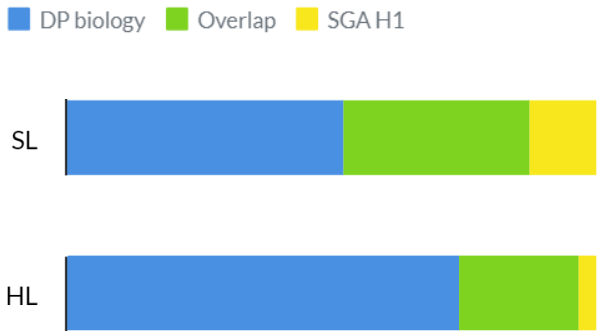
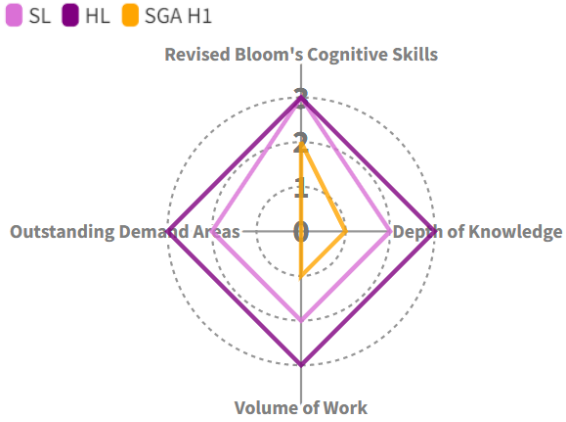
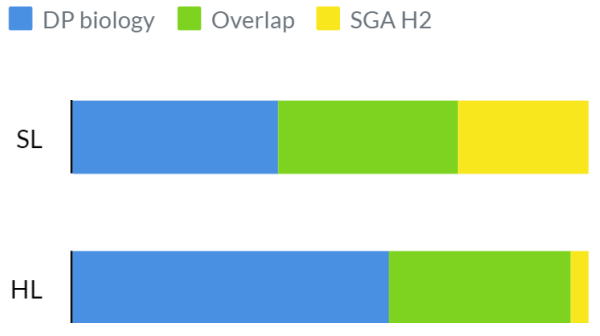
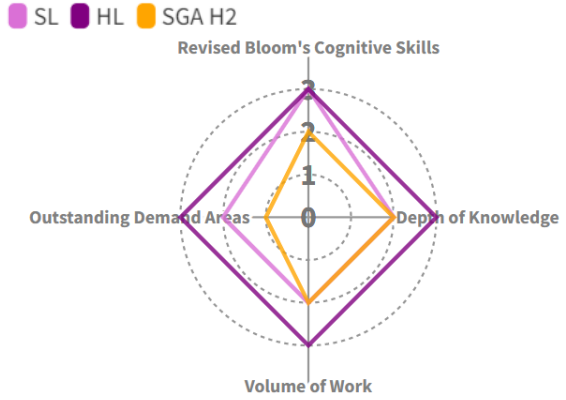
Subject name	Learning outcomes alignment	Content alignment	Demand alignment
H1 mathematics	Low Moderate **High**		
H2 mathematics	Low Moderate **High**		

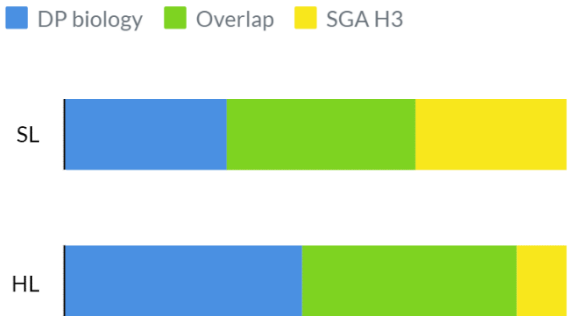
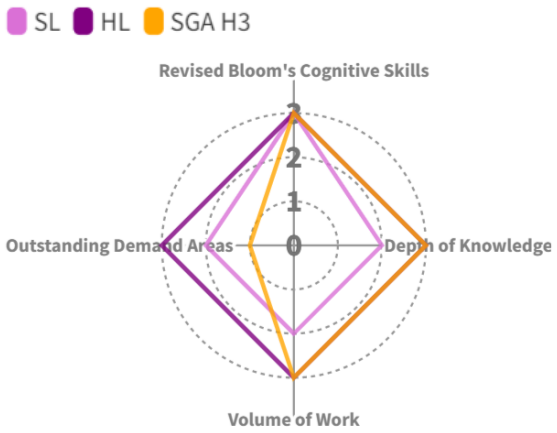
Subject name	Learning outcomes alignment	Content alignment	Demand alignment
H2F mathematics	Low Moderate **High**		
H3 mathematics	Low Moderate **High**		

Subject name	Learning outcomes alignment	Content alignment	Demand alignment
H1 physics	Low Moderate **High**		
H2 physics	Low Moderate **High**		

Subject name	Learning outcomes alignment	Content alignment	Demand alignment
H3 physics	Low Moderate **High**		
H1 chemistry	Low Moderate **High**		

Subject name	Learning outcomes alignment	Content alignment	Demand alignment
H2 chemistry	Low Moderate **High**		
H3 chemistry	Low Moderate **High**		

Subject name	Learning outcomes alignment	Content alignment	Demand alignment
H1 biology	Low Moderate **High**		
H2 biology	Low Moderate **High**		

Subject name	Learning outcomes alignment	Content alignment	Demand alignment
H3 biology	Low Moderate **High**		

As well as alignment judgements, the analysis also uncovered various similarities and differences between the DP and comparison subjects. Key highlights are summarised below.

Mathematics

- **Learning outcomes alignment**: the level of alignment between both DP mathematics subjects, at both SL and HL, and the SGA courses' learning outcomes is significant, as nearly all DP themes are present in the SGA curricula.

- **Content alignment**: the level of content alignment between DP mathematics subjects and SGA courses varies. For H1, there is reasonable alignment with DP SL, though the former has less content than the latter, and significantly less than DP HL. There is high alignment between H2 mathematics and AA HL, as the majority of content is overlapping. There is slightly less, but still considerable, alignment between H2 and AI HL. When considering H2F, in addition to H2, it can be observed that there is a greater breadth and depth of content studied compared to DP HL subjects. Similarly, when H3 is offered with H2, the content of DP HL is exceeded – through depth and practice of rigour, rather than breadth. Overall, the content within H1 and H2 is very similar to the DP curriculum, with H2 being of comparable size to DP HL, whereas the content of H2F and H3 goes beyond the scope of what is offered in the DP.

- **Demand alignment**: SGA H1 is surpassed in most demand categories by both DP SL and HL. SGA H2 scores similarly to DP HL for depth of knowledge, but its lower scores for outstanding areas of demand and volume of work mean that it is generally more similar to the demand of DP SL. H2F and H3 demand scores are very comparable to DP HL subjects, scoring highly for cognitive skills, depth of knowledge, volume of work, and outstanding areas of demand.

Physics, chemistry, and biology

All DP science subjects – physics, chemistry and biology – have been individually analysed and compared against the designated comparison subject. However, as they share a number of similarities – for instance, the same learning outcomes, assessment objectives and assessment requirements – the findings for all courses were similar and are, thus, collectively presented below.

- **Learning outcomes alignment**: the level of alignment between the learning outcomes of DP and SGA science subjects is significant, with nearly all themes extracted from the DP learning outcomes being present in the SGA's learning outcomes.

- **Content alignment**:
    - Physics: H1 content lacks the breadth and depth to be comparable to either SL or HL, though does have some significant overlapping content with certain SL topics. H2 has similar breadth to DP physics and somewhat surpasses SL in depth, though only with the addition of H3 is the depth comparable to that of DP HL. All SGA subjects, especially H2 and H3, have some sub-topics which are not in the DP, and slightly differ in their coverage of certain sub-topics.

  - Chemistry: there is a large amount of overlapping chemistry content between the DP and SGA curricula. H2 covers nearly all SL and HL sub-topics, therefore there is a high level of alignment and comparability in breadth and depth of study when H2 is studied, which is only slightly higher if H3 is also studied, as the latter explores only a small number of concepts in further depth. H1 also includes a significant amount of SL content and is comparable with the latter in breadth and depth.
  - Biology: the alignment between SGA and DP biology content is generally moderate, due to a lack of overlapping content. The majority of SL and HL topics are not present in H1, which has less breadth and depth than both SL and HL. There is moderate alignment with H2, and slightly more so if H3 is also studied; however, there are still significant DP content areas that are not covered in the SGA syllabi, especially sub-topics within topic A. Unity and Diversity. Overall, SGA biology subjects have less breadth and depth of content than DP HL.

- **Demand alignment**:
  - For all SGA science subjects, H1 is surpassed in all demand categories by both SL and HL, whereas H2 and H3 score similarly to DP SL and DP HL, respectively.

Summary

The programme-level features of the DP and SGA are highly aligned. The two programmes observe similar philosophical underpinnings and share similarities in their assessment approaches, though they differ somewhat in their entry requirements and student learning pathways. At subject-level, alignment between the SGA and DP is generally high, though it varies across subjects. For mathematics, alignment levels are highest when comparing the DP's HL subjects with H2, while H1 falls short of the DP in content and demand, and H2F and H3 share similar demand levels with the DP HL course but cover more content than what is featured in the DP. As for science subjects, there is varying alignment, with SGA physics and chemistry judged to be highly aligned with the DP, and SGA biology considered to be moderately aligned. In each case, H1 falls short of the comparison DP subject at both SL and HL, except for H1 chemistry which has significant overlap with the DP at SL. Both H2 and H3 physics and chemistry have significant alignment with the DP at SL and HL, respectively, while the alignment of both H2 and H3 biology with the DP is lower at both SL and HL due to more substantial differences in content coverage.

2. Introduction

2.1 Context and Scope

The International Baccalaureate (IB) Organization is a not-for-profit educational foundation offering four programmes across the world, including the Primary Years Programme (PYP), Middle Years Programme (MYP), Diploma Programme (DP) and the Career-related Programme (CP). The DP – the IB's two-year upper secondary Diploma Programme – is conceived as a preparatory programme for university matriculation and higher education, aimed at developing students with 'excellent breadth and depth of knowledge' who 'flourish physically, intellectually, emotionally and ethically'.[3]

Ecctis was commissioned by the IB to deliver a series of critical and in-depth alignment studies to assess the level of alignment between the DP and comparison points within the upper secondary education systems of Australia, Canada, the USA, Singapore, South Korea, and Finland.[4] More specifically, the studies aim to identify areas of similarities and differences between the DP and these educational systems by comparing philosophical underpinnings, structure, requirements, assessment methods, learning pathways, content, and specifically to determine how the DP compares to the selected benchmarks in terms of intended student learning outcomes at subject level. The studies include, for all countries, a focus on mathematics and the sciences, with an additional focus on history for Australia, and English for the USA.

Ultimately, this series of comparative studies aims to inform the IB's development of tools and resources for IB teachers, helping them navigate between the IB and the local curriculum in the target countries where needed. In doing so, it also contributes to further supporting fair recognition of the DP by institutions, employers, and other key stakeholders, supporting progression and mobility for DP graduates.

This report constitutes one of the project's deliverables and aims to specifically answer the research questions pertaining to how the DP aligns with the Singaporean upper-secondary programme of education. As agreed with the IB, this report focuses specifically on the Singaporean GCE A Level (SGA) programme.

2.2 Research Questions

All comparative studies in this series have been framed by responses to Research Questions (RQs), both at programme level and subject level. For this study specifically, the RQs are as follows:

[3] International Baccalaureate. (2022). *Diploma Programme*. https://www.ibo.org/programmes/diploma-programme/
[4] The series of studies responds to the following Request for Proposals (RFP), issued by the IB: *The International Baccalaureate Diploma Programme: Alignment with Australian and Canadian Upper Secondary Education; Request for Proposals (RFP): The International Baccalaureate Diploma Programme: Alignment with the US Common Core State Standards (CCSS) and the New Generation Science Standards (NGSS); Request for Proposals (RFP): The International Baccalaureate Diploma Programme: Alignment with Singaporean, Korean and Finnish Upper Secondary Education.*

Singapore Research Questions

Table 1: Singapore research questions

RQ1: To what degree does the DP curriculum align with the Singaporean upper secondary curriculum? In what way are the curricula similar and in what way are they different in demand and difficulty? To what degree are the curricula compatible?

RQ2: To what degree do the curricula align with regard to their:

2.1: Philosophical underpinnings
- Objectives
- Principles
- Values.

2.2: Structure
- Learning areas
- Subject offerings
- Degree of specialization
- Time allocation.

2.3: Requirements
- Programme entry requirements
- Time requirements (i.e. programme duration, teaching hours, study hours)
- Certificate requirements (i.e. credits, passing and failing conditions, compensation options).

2.4: Assessment
- Nature of assessment (i.e. number, type, duration, question types, availability of marks)
- Assessment model (i.e. relative weighting of assessments to overall grades).

2.5: Student learning pathways
- Degree of specialization
- Options in subject (area) choice (i.e. compulsory subjects, electives).

RQ3: To what degree do the subjects[5] align with regard to:

3.1: Content
- Topics (i.e. scope of content area, breadth, depth)
- Learning activities (i.e. difficulty, demand).

3.2: Expected learning outcomes
- Knowledge
- Competencies (i.e. subject-specific, 21st century competencies).

With regard to subjects to be compared in the subject-level comparative analysis, the following table indicates the agreed scope:

Table 2: Subject areas for comparison of the DP and the SGA

DP subject (group)	Singapore subjects
SCIENCES	
physics SL and HL	Higher 1 (H1) physics Higher 2 (H2) physics Higher 3 (H3) physics
chemistry SL and HL	Higher 1 (H1) chemistry Higher 2 (H2) chemistry Higher 3 (H3) chemistry
biology SL and HL	Higher 1 (H1) biology Higher 2 (H2) biology Higher 3 (H3) biology

[5] With regard to subjects within scope, see Table below.

MATHEMATICS	
mathematics: analysis and approaches (AA) SL and HL	Higher 1 (H1) mathematics Higher 2 (H2) mathematics Higher 2 further (H2F) mathematics Higher 3 (H3) mathematics
mathematics: applications and interpretation (AI) SL and HL	

All DP curricula have been considered at both standard level (SL) and higher level (HL).

2.3 Report Structure

In responding to the above RQs, this report included the following sections:

- 3. Methodology: this section provides a brief overview of the methodology applied in this study. This includes details of how the document selection and identification of comparison points for the study took place; a definition of 'alignment'; an outline of the methodology used for comparisons at both programme and subject levels; and an outline of the methodology used to assess demand.

- 4. Programme-Level Alignment: this section presents the synthesised analysis from the programme-level comparisons between the DP and the Singaporean pre-university curriculum. In doing so, it includes brief programme overviews for both qualifications, followed by the comparative analysis on their philosophical underpinnings, structure, requirements and associated outcomes, student learning pathways and the general nature of assessment practices.

- 5. Subject-Level Alignment: this section presents the synthesised analysis from the subject-level comparisons between DP and Singaporean pre-university curriculum subjects. For each comparison subject, this includes the comparative analysis on their learning outcomes, content, and demand.

- 6. Key Findings: this section outlines the key findings from both the programme- and subject-level comparisons undertaken in this study. In doing so, it provides a top-level conclusion on alignment at both programme and subject levels, and a succinct summary of key similarities and key differences.

- 7. Bibliography: this section references all sources cited in the study, including the documents used for both programme- and subject-level curriculum analyses.

3. Methodology

3.1 Document Selection and Identification of Comparison Points

To undertake these comparative analyses, the following core documentation was reviewed (supplemented by additional documentation – detailed in the Bibliography – where relevant and available):

IB Documentation

- What is an IB education? (WIAIBE)
- WIAIBE Teacher Support Material
- DP: From Principles into Practice
- Programme Standards and Practices
- DP subject guides:
    - mathematics: analysis and approaches
    - mathematics: applications and interpretation
    - physics
    - chemistry
    - biology.

Singapore Documentation

- Ministry of Education – Singapore (website)[6]
- Ministry of Education – Singapore's Post-Secondary Education booklet, including information about underpinning philosophy and pedagogy[7]
- The Singapore Curriculum – Pre-University Subject Syllabuses:[8]
    - H1, H2, H2F, and H3 mathematics
    - H1, H2 and H3 physics
    - H1, H2 and H3 chemistry
    - H1, H2 and H3 biology.

Philosophical Underpinnings Comparison

For the programme-level comparisons between the philosophical underpinnings of each programme, Ecctis used the following elements of the curriculum documentation:

[6] MOE, Singapore. (2022). *Post-Secondary.* Available from: https://www.moe.gov.sg/post-secondary

[7] MOE, Singapore. (2021). *Post-Secondary Education.* Available from: https://www.moe.gov.sg/-/media/files/post-secondary/post-secondary-school-booklet-2021

[8] MOE, Singapore. (2022). *A Level curriculum and subject syllabuses.* Available from: https://www.moe.gov.sg/post-secondary/A Level-curriculum-and-subject-syllabuses

Table 3: Philosophical underpinnings for comparison of the DP and the SGA

Documentation containing philosophical underpinnings	
DP	**Singapore**
'What is an IB Education', particularly the following sections: ○ IB learner profile ○ International-mindedness ○ Approaches to teaching and approaches to learning (ATL).[9]	Ministry of Education Singapore website, particularly the following pages: ○ Singapore Curriculum Philosophy[10] ○ Desired Outcomes of Education[11] ○ 21st Century Competencies[12]

The document 'What is an IB Education?' provides detailed information about the IB's educational philosophy. For the SGA, the philosophy and pedagogy are articulated in the Singaporean 'curriculum philosophy',[13] the 'desired outcomes of education'[14] and the 'framework for 21st century competencies',[15] all found in the Ministry of Education's (MOE) website.

For more information on the mapping process, see the Measuring Alignment section below.

Learning Outcomes Comparison

For the Learning Outcomes comparisons, as neither of the two qualifications explicitly defines 'learning outcomes' in their curriculum documentation, Ecctis used the following categories of the curriculum documentation for comparison:

Table 4: Learning outcomes for comparison of the DP and the SGA

DP subject (group)	**Categories utilised as learning outcomes**
SCIENCES	
physics	DP sciences subject group – aims and assessment objectives
chemistry	
biology	
MATHEMATICS	
mathematics: analysis and approaches	DP mathematics subject group – aims and assessment objectives
mathematics: applications and interpretation	
Singaporean subjects	**Documentation and Sections**
SCIENCES	
H1, H2, and H3 physics	Practices of Science, Syllabus Aims
H1, H2, and H3 chemistry	Practices of Science, Syllabus Aims
H1, H2, and H3 biology	Practices of Science, Syllabus Aims
MATHEMATICS	
mathematics H1, H2, H2F, H3	Mathematics Curriculum Framework, Mathematics and 21CC, Syllabus Aims

[9] International Baccalaureate. (2017). *What is an IB Education?*
[10] MOE, Singapore. (2021). *Singapore Curriculum Philosophy*. Available from: Singapore Curriculum Philosophy | MOE
[11] MOE, Singapore. (2021). *Desired Outcomes of Education.* Available from: Desired Outcomes of Education | MOE
[12] MOE, Singapore. (2021). *21st Century Competencies.* Available from: 21st Century Competencies | MOE
[13] MOE, Singapore. (2021). *Singapore Curriculum Philosophy*.
[14] MOE, Singapore. (2022). *Desired Outcomes of Education.*
[15] Ibid.

Although not labelled as learning outcomes per se, the above categories were chosen as they were deemed to provide the most complete picture of the skills and knowledge that students should obtain upon completion of each subject.

For more information on the mapping process, see the Measuring Alignment section below.

3.2 Measuring Alignment (Similarities and Differences)

Alignment is a key concept for this series of studies. The aim of this study is to unpick the level of alignment between the DP and the SGA. Although Ecctis has sought to represent the alignment findings as straightforwardly as possible in this report, alignment is not a simple concept, so it is important to establish Ecctis' approach in this regard.

Alignment, as a term, is often used in education circles to refer to *internal* coherence between learning outcomes, assessment methods, teaching practices and other features of teaching and learning. This report does not consider *internal* alignment, but what might appropriately be labelled *external* alignment. Alignment of this type looks at the extent to which a programme (in this case, the DP) aligns with other educational programmes (in this case, the SGA). This form of external alignment is particularly key to understand for an organisation like the IB which operates in so many international contexts, often alongside national curricula, where teachers and students may seek to move back and forth between IB and national streams of education.

Within this narrower definition of *external* alignment, the idea is still broad and could be seen from any number of perspectives. In this series of studies, the IB has specifically asked Ecctis to consider alignment from the specific perspectives outlined by the RQs. The RQs thereby define the limits of the type of alignment that will be considered within the reports. Namely:

- At the programme level:
    - Alignment of philosophical underpinnings
    - Alignment of structure
    - Alignment of requirements and associated outcomes
    - Alignment of student learning pathways
    - Alignment of approaches to assessment.

- At the subject level (in selected subjects):
    - Alignment of learning outcomes
    - Alignment of content
    - Alignment of demand.

To form a comprehensive picture of alignment, Ecctis' approach has used multiple repeating steps within each report. For Singapore, it sought to:

- Analyse to what extent the SGA has similarities with the DP.
- Analyse to what extent the SGA lacks features contained within the DP.
- Analyse to what extent the DP lacks features contained within the SGA.

In this respect, **alignment is a measure of the extent to which there are similarities and differences between key selected criteria of two educational programmes**. High

alignment indicates significant similarities, with few differences in key areas, whereas low alignment results from many differences in important aspects, with perhaps only few or non-impactful similarities. Alignment judgements in this study took a holistic view of similarities and differences and the likely impact these will have on what skills and knowledge students possess upon completion of a programme of study. As such, the study did not use fixed, quantitative criteria to differentiate high from low alignment, but rather produced informed, holistic judgements drawing on an outcomes-focused perspective.

Mapping

To accurately measure the alignment of the DP to the SGA, it is necessary to map the similarities and differences across the selected alignment criteria. This necessitates identification of the same structural features in the DP and in the SGA (the comparison programme) so that a mapping process can be undertaken.

Mapping, in this case, refers to detailed analysis of a feature of an education programme (generally as represented within that programme's documentation). Specifically, mapping applies the same analytical method to two separate sets of data (for example, the learning outcomes of two different curricula), enabling similarities and differences between those two data sets to be understood through the different results of applying the same mapping method to both. Another important feature of mapping is that there is a paper trail of the analysis, as the approach is methodical, testable, and repeatable.

For more information on how mapping has been applied in this study, see sections 3.2.1 and 3.2.2.

3.2.1 Method: Programme-Level Comparison

Each aspect of the programme-level comparison is achieved through slightly different approaches to mapping and assessing alignment, the results of which inform the overall alignment evaluation. Each method is described in the appropriate subsection below.

Philosophical Underpinnings

In the DP, the ATL, the learner profile, and the framework of international-mindedness were used to represent the philosophical underpinnings, while the 'Singapore curriculum philosophy'[16], 'desired outcomes of education'[17] and 'framework for 21st century competencies'[18] sections were used for the SGA.

In order to carry out the comparative analysis, six themes were extracted from the DP's philosophical underpinnings:

[16] MOE, Singapore. (2021). *Singapore Curriculum Philosophy*.
[17] MOE, Singapore. (2022). *Desired Outcomes of Education.*
[18] Ibid.

Table 5: Philosophical underpinning themes

Philosophical underpinning themes
• International outlook, diversity, and intercultural understanding • Grounded in real world contexts • Principled and community-oriented • Independence/self-management, critical inquiry, and reasoning • Communicative and collaborative competency • Conceptual thought and understanding.

This list of themes was mapped against both the DP's philosophical underpinnings and the philosophical underpinnings of the SGA to identify what aspects of the DP's philosophical underpinnings are shared with the SGA and what aspects are unique to either the SGA's philosophical underpinnings or the DP's. The detail of this mapping was carried out in the mapping spreadsheets, while a visual summary and written explication of the findings can be found in the Philosophical Underpinnings section below (see section 4.2).

Structure

Comparing the structures of the DP and a national programme does not require a mapping process. Instead, subject offerings, how duration interacts with subjects/progression, and the general structure of the qualification (including exit points) have been represented with visuals for each programme. These curriculum structure diagrams use block colours and simple box and arrow graphics to demonstrate structure and progression.

Curriculum structure diagrams have been placed next to each other in this report to show the similarities and differences at a glance. The visual presentation is followed by a short write-up of the key similarities and differences, to maintain analytical focus on the alignment of the two programmes.

Requirements and Associated Outcomes

The requirements and associated outcomes of each programme are, like the structure, also simple, core features which do not require a mapping process in order to be compared. Comparisons and contrasts are drawn between the different requirements (e.g. entry requirements, pass/fail requirements) linked to both programmes and the associated outcomes of both.

Student Learning Pathways

By 'student learning pathways', we refer to the learning route that each student can take through a programme – with focus on scope for subject-specific specialisation. As with the comparative analysis of structure, diagrams resembling flow charts have been used to visually demonstrate the core and optional subject choices, providing an example to indicate how students follow different potential learning pathways in both programmes. A short textual write-up has been included after the diagrams to highlight and discuss the key similarities and differences – maintaining analytical focus on the issue of alignment.

Assessment Methods

Although detailed comparative analysis of assessment is not a main component of the analysis of alignment, Ecctis has briefly considered the high-level assessment features within the programmes being compared.

A simple table has been used, followed by a short textual description of the key similarities and differences. Where possible, the types/numbers of assessment used in the programme are a source of comparison, and the subjects analysed in the subject-level alignment analysis in each report have been used as examples to consider assessment in more detail (i.e. question types and marking approaches, where this information is available).

3.2.2 Method: Subject-Level Comparison

As previously described, a number of subjects has been selected by the IB for a closer look at alignment at the subject level. This includes a closer look at the learning outcomes for each subject, the subject content, and the demand level. Each approach is outlined below.

Learning Outcomes

To analyse the alignment of learning outcomes at the subject level, the process began by extracting six to eight themes from the DP's subject-level learning outcomes for each subject being analysed, encompassing both skills and knowledge areas. This thematic code was then mapped onto the learning outcomes of the DP subject and the comparison subject from the SGA.

The top-level results of the mapping process are represented with a table per subject area. Following the tables, a written commentary is provided regarding the presence of DP knowledge areas and skills (represented by themes) in the SGA and any knowledge areas and skills found in the SGA but not in the DP.

Content

To compare the content of the DP subject and the comparison SGA subject, both are first presented next to each other in the document in a simple tabular format. Additionally, content mapping took place through a simple process of establishing whether each content sub-topic covered by the DP subject in question has 'clear alignment' with any content in the SGA comparison subject. The mapping spreadsheets demonstrate the full logic of all judgements.

A commentary is provided on DP subject content not found to have alignment points in the SGA subject and on SGA subject content topics not found to have alignment points in the DP subject.

Demand

Comparing the demand of subject curricula is perhaps the most complex mapping and alignment analysis within this report. Ecctis' approach views demand from multiple perspectives to capture its relationship to skills as well as to the detail and scope of content.

To allow for a comprehensive assessment of the level of demand of the DP selected subjects against the respective comparison points, Ecctis has created a Demand Profile for each

subject in the study. Each Demand Profile comprises four criteria designed to judge complexity, depth, breadth, workload levels and potential for intellectual stretch. These criteria have been applied uniformly across all subjects in the study, using an expert panel-approach (as outlined below).

Demand Profile – Subject-level Judgement

The Demand Profile is comprised of four scores (each between zero and three) based on specific criteria. Each score within each category has a specific definition which is listed in Appendix A. A panel of subject, teaching, and curriculum design experts analysed each subject curriculum and arrived at a consensus on which score descriptor in each category best matched with the curriculum in question. The categories which comprise the Demand Profile are as follows:

- **Revised Bloom's Cognitive Skills** score (0-3): this is an overall score of course demand, based entirely on a review of learning outcomes. Levels have been defined based on increasing emphasis of higher order cognitive skills taken from Bloom's Revised Taxonomy.[19]

- **Depth of Knowledge** (adapted from Webb's) score (0-3): this is an overall score evaluating the depth of knowledge or complexity of knowledge and skills required by curriculum standards and expectations. The score is focused on subject content and learning outcomes, complemented by assessment where relevant/possible. Levels have been defined based on the level of detail studied per topic, as well as the levels of thinking described in Webb's Depth of Knowledge framework.[20]

- **Volume of Work** score (0-3): this is a trifactor score, considering:
  a. breadth of content – i.e. how many topic and sub-topics are covered
  b. depth of content – i.e. the extent to which the topics and sub-topics are focused upon, amplified and explored.[21]
  c. specified timeframe – i.e. the time allocated for studying the subject.

  The three factors – breadth, depth, and time – were all considered in defining the levels.

- **Outstanding Areas of Subject Demand** score (0-3): this score reflects the number of content areas viewed as more challenging and/or conducive to intellectual stretching of students. Levels have been defined on a scale of increasing number of 'stretch areas'.

Demand Panel: Expert Judgement Procedure

Demand analysis and judgements against the above criteria rested with a panel of experts comprised of both curriculum and teaching experts – i.e. international education researchers experienced in comparative secondary curriculum evaluation – and subject experts – i.e.

[19] Krathwohl, D. (2002). A Revision of *Bloom's taxonomy: An Overview.* Theory Into Practice, Vol 41(4). Available from: www.tandfonline.com/doi/abs/10.1207/s15430421tip4104_2?journalCode=htip20

[20] Webb, N. L. (2002). *Depth-of-knowledge levels for four content areas*. Language Arts. Available from: Microsoft Word - Webb DOK all content.doc (pbworks.com)

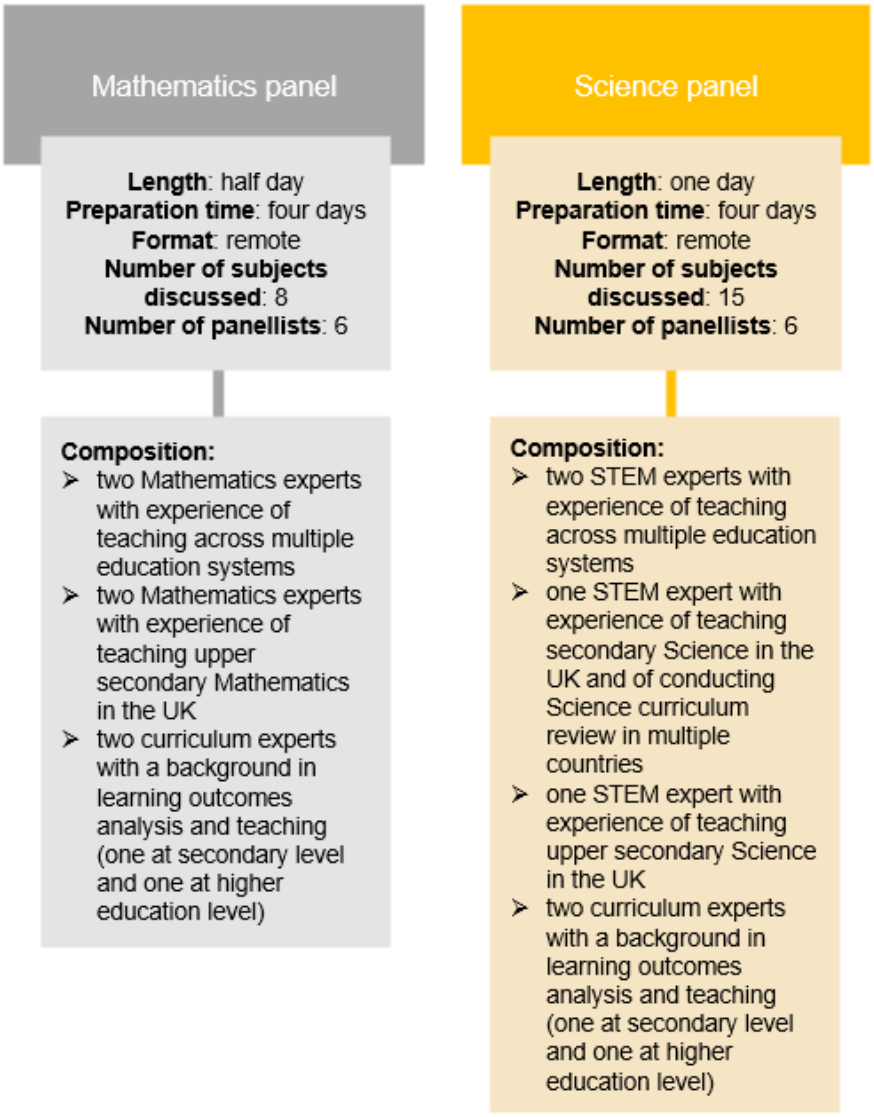
[21] Note: 'depth of content' primarily describes what is on the curriculum (i.e. the level of detail comprised in each topic), whereas 'depth of knowledge' describes what the students need to be able to do (i.e. how complex and extensive the thinking processes involved are).

researchers and consultants with a subject specialism in the relevant subject areas. For both expert types, teaching experience, understanding of appropriate national/international teaching contexts, and experience of curriculum and learning outcomes comparisons were prioritised.[22]

For the panels discussing the demand level of the DP subjects and respective comparison subjects in the Singapore, Finland and South Korea reports, the composition of each panel was as follows:

[22] To minimise potential biases and subjectivity, Ecctis' recruitment procedure excluded candidates with experience of teaching any of the comparison qualifications in this study.

Figure 1: Demand panels details



All panellists were provided with the relevant extracts from the appropriate qualifications' specifications, including (where available):

- Learning outcomes and aims of the qualification
- Assessment structure
- Information about guided learning hours or curriculum time
- Assessment objectives
- Content.

The experts were also provided with a document containing:

- An introduction to the comparative analysis task
- Descriptions of the demand taxonomies
- The demands instrument (used to record findings).

Panellists conducted between three and four days of panel preparation, reviewing the appropriate curriculum documentation in detail and scoring each subject against the demand criteria provided (the template utilised for this has been included in Appendix C). Following this preparation, participants then took part in their respective panels, which were all hosted remotely on Microsoft Teams. The science demand panel lasted one full working day, while the mathematics panel lasted for half a day due to the lower number of subjects being discussed.

All judgements resulted in scores from 0-3 for each demand criterion mentioned above, with each score for each criterion being pulled into each course's demand profile. The panel approach was used to debate the findings and scores reached by each member of the panel and arrive at an evidence-based consensus on every demand score for every subject.[23]

Visually, each demand profile is represented by radar diagrams to facilitate demand comparison between subjects.

NB: all demand scores produced should be interpreted as approximate judgements given the varying degrees of documentation and detail available for each curriculum, as well as likely variation on how the curricula are implemented in practice.

[23] Note: each score was debated by the panel until a unanimous agreement was reached.

4. Programme-Level Alignment

This section focuses on answering RQ2 and the sub-questions associated with it, namely:

Table 6: Research question 2

RQ2: To what degree do the curricula align with regard to their: 2.1: Philosophical underpinnings • Objectives • Principles • Values? 2.2: Structure • Learning areas • Subject offerings • Degree of specialization • Time allocation? 2.3: Requirements • Programme entry requirements • Time requirements (i.e. programme duration, teaching hours, study hours) • Certificate requirements (i.e. credits, passing and failing conditions, compensation options)? 2.4: Assessment • Nature of assessment (i.e. number, type, duration, question types, availability of marks) • Assessment model (i.e. relative weighting of assessments to overall grades)? 2.5: Student learning pathways • Degree of specialization • Options in subject (area) choice (i.e. compulsory subjects, electives)?

It starts by offering top-level overviews of both the DP and the SGA, followed by presenting the results from the programme-level comparative analysis for each core component outlined above.

4.1 Programme Overviews

4.1.1 The International Baccalaureate Diploma Programme

The Diploma Programme (DP) was established in 1968 as a two-year pre-university programme for 16–19-year-old students.[24]

Students who aim to achieve the Diploma award must generally select one subject from each of the six subject groups:

- Studies in language and literature
- Language acquisition
- Individuals and societies
- Sciences
- Mathematics

[24] International Baccalaureate. (2015). *Diploma Programme. From principles into practice*. p. 5.

- The arts.[25]

Students who do not wish to take a subject from the arts subject group may opt to study an additional sciences, individuals and societies, or languages course instead.

All subjects are studied concurrently over the two-year duration of the programme and most subjects can be taken at either HL or SL. In terms of teaching hours, the DP's documentation recommends 150 teaching hours for individual subjects at SL and 240 teaching hours are at HL.[26]

In addition to the six subjects taken from these groups, DP students will also need to complete three further curriculum components. Theory of knowledge (TOK) allows students to reflect on the nature of knowledge by considering their subjects from a broader perspective.[27] The extended essay is a self-directed piece of research which results in a 4000-word essay.[28] Creativity, activity, service (CAS) is not formally assessed but requires that students undertake a creative endeavour, take part in something physically active, and participate in a voluntary or unpaid activity.[29] Together, these three components comprise the DP 'core'.

To achieve the IB Diploma a student must take at least three HL subjects.[30] The maximum number of subjects that can be taken at higher level is four. HL subjects are intended to prepare learners for the discipline specialisation of higher education, whilst the SL subjects balance this by broadening the range of subjects studied.[31]

The DP curriculum framework is based on a concentric circle model (see below), whereby the learner profile is positioned at the centre to represent its relevance to all aspects of the programme. The next circle comprises the core requirements of TOK, the extended essay, and CAS. The six subject groups are then encircled by international-mindedness and the programme title – indicating that everything students study is unified by the underpinning philosophy of encouraging thinking from a perspective that embraces other points of view outside one's own frame of reference.

[25] International Baccalaureate. (2021). *Curriculum*. Available from: https://www.ibo.org/programmes/diploma-programme/curriculum/
[26] Ibid.
[27] International Baccalaureate. (2021). *Theory of knowledge*. Available from: https://www.ibo.org/programmes/diploma-programme/curriculum/theory-of-knowledge/
[28] International Baccalaureate. (2016). *Guide to the International Baccalaureate Diploma Programme*. p.2.
[29] International Baccalaureate. (2021). *CAS projects.* Available from: https://www.ibo.org/programmes/diploma-programme/curriculum/creativity-activity-and-service/cas-projects/
[30] International Baccalaureate. (2021). *Curriculum*.
[31] International Baccalaureate. (2015). *Diploma Programme. From principles into practice*. p.6.

Figure 2: IB Diploma Programme curriculum model[32]

Both internal and external assessment methods are used in the DP. In most subjects, students take written examinations at the end of the programme that are marked by external IB examiners. Internally assessed tasks normally comprise between 20-30% of the total mark in each subject.[33,]

Question types used in DP assessment vary from subject to subject. Essays, structured problems, short-response questions, data-response questions, case-study questions, and multiple-choice questions are some of the external assessment question types deployed.[34] Coursework forms part of the assessment for areas of the DP such as the extended essay and TOK.[35] This is normally carried out over an extended period under teacher supervision. Where students complete internally assessed tasks, these are marked by teachers and moderated by the IB.[36] Some of the internal assessment methods used include oral work in languages, fieldwork in geography, laboratory work in the sciences, and artistic performances in the arts.[37]

Each DP subject, whether taken at SL or HL, is graded from 1-7 (with 7 representing the highest achievement level).[38] If a student has taken enough subjects at the correct level to be

[32] International Baccalaureate. (2016). *Guide to the International Baccalaureate Diploma Programme*. p. 2.
[33] International Baccalaureate. (2021). *Understanding DP assessment*. Available from: https://www.ibo.org/programmes/diploma-programme/assessment-and-exams/understanding-ib-assessment/
International Baccalaureate. (2014). *Diploma Programme: A guide to assessment*. p. 3.
[34] International Baccalaureate. (2021). *Assessment and Exams*. Available from: https://www.ibo.org/programmes/diploma-programme/assessment-and-exams/
[35] International Baccalaureate. (2021). *Understanding DP assessment*.
[36] Ibid.
[37] International Baccalaureate. (2021). *Assessment and Exams*.
[38] International Baccalaureate. (2021). *Understanding DP assessment*.

in contention for the Diploma award, a minimum of 24 points is needed to achieve the qualification. A minimum grade of 3 is also needed in at least four subjects to achieve the qualification.[39]

Additionally, 42 total points are available from the combination of the grades for six subjects and a further three points are available to students for successful completion of the core elements of TOK, the extended essay, and CAS. The TOK and extended essay components of the DP are each marked on an A-E scale, where an A grade is the highest award, and an E grade the lowest.[40] Their combined results can contribute up to three additional numerical points to the overall DP score (see **Error! Reference source not found.** below). CAS does n ot constitute a graded part of the DP, although its completion is mandatory to be awarded the Diploma.

Table 7: Letter-Grade: numerical score conversion matrix[41]

		Theory of knowledge (TOK)				
	Grade awarded	A	B	C	D	E
The extended essay	A	3	3	2	2	Failing condition
	B	3	2	2	1	
	C	2	2	1	0	
	D	2	1	0	0	
	E	Failing condition				

HL and SL subjects are assessed against the same grade descriptors;[42] however, HL candidates are expected to demonstrate the various elements of the grade descriptors across a greater range of knowledge, skills, and understanding.

A bilingual Diploma is awarded to students who achieve:

- Grade 3 or higher in two language subjects from subject group 1, or,
- Grade 3 or higher in a group 1 language subject and a grade 3 or higher in a group 3 or 4 subject taken in a different language.

Certificates are awarded to students that have taken individual subjects but not enrolled on the full Diploma, or DP candidates who do not complete the full DP.[43] Prospective candidates can enrol in as many individual subjects as permitted by their school; these are graded with the same 1-7 system used in the full DP.

No formal entrance requirements are stipulated as the IB envisages numerous educational pathways leading to the DP.[44] However, the IB recommends consulting the subject guides prior to enrolment to ensure an adequate understanding of programme expectations.[45]

[39] International Baccalaureate. (2016). *Guide to the International Baccalaureate Diploma Programme*. p.4.
[40] Ibid.
[41] International Baccalaureate. (2017). *Assessment principles and practices: Quality assessments in a digital age*. p.220.
[42] International Baccalaureate. (2021). *Understanding DP assessment*.
[43] International Baccalaureate. (2016). *Guide to the International Baccalaureate Diploma Programme*. p.4.
[44] International Baccalaureate. (2015). *Diploma Programme. From principles into practice*. p.22.
[45] Ibid.

4.1.2 SGA programme

The school system in Singapore is overseen by the Ministry of Education (MOE). It is divided into primary school (six years/grades) secondary school (four to five years/grades), and post-secondary/pre-university education (two to three years/grades).[46] Notably, students who leave secondary education can pick an institution type – e.g. junior colleges (JCs), the Millenia Institute (MI), Polytechnics, Institute of Technical Education (ITEs), specialised schools in the areas of sports or arts, among others – based on their interests, abilities, and aspirations.[47] This report focuses on the SGA curriculum taught at junior colleges and centralised institutes, which leads to the GCE A Level examination[48] (see Assessment section below) and represents the most common route to higher education.

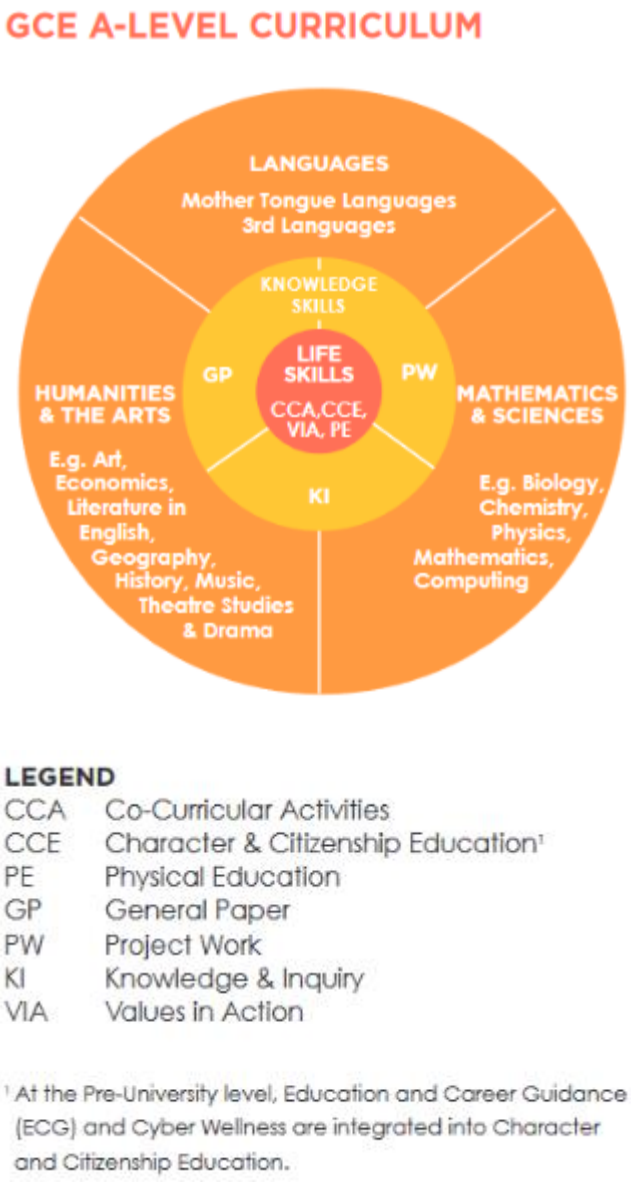
Structure

The SGA curriculum is taught over two to three years (two years in JCs and three in MI) and includes courses organised into three main groups:

- Life skills: co-curriculum activities, character and citizenship education, physical education, and values in action
- Knowledge skills: general paper, knowledge and inquiry, and project work
- Content-based subjects: various courses offered within the subject areas of:
    - languages
    - humanities and the arts
    - mathematics and sciences.[49]

[46] MOE, Singapore. (2022). *Post-secondary Education Booklet*. Available from: post-secondary-education-booklet-2022.ashx (moe.gov.sg)
[47] Ibid.
[48] SEAB. (2022). *GCE A Level*. Available from: www.seab.gov.sg/home/examinations/gce-A Level
[49] MOE, Singapore. (2022). *A Level curriculum and subject syllabuses.* Available from: www.moe.gov.sg/post-secondary/A Level-curriculum-and-subject-syllabuses

Figure 3: SGA curriculum model[50]



Within these, there is flexibility and diversity in students' choice of subject combinations, with subjects being offered at three levels which candidates can choose from. These levels of study are structured to cater to students' interests and abilities, and include the following:[51]

- Higher 1 (H1) level
- Higher 2 (H2) level
- Higher 3 (H3) level.

H2 is double the size of H1 in terms of curriculum time and thus enables a greater breadth and depth of content to be studied.[52] The syllabi are designed such that students study **either**

[50] MOE, Singapore. (2022). *Post-secondary Education Booklet*.
[51] Ibid.
[52] MOE, Singapore. (2015). *The 'A' Level Experience. Levels of Study.* Available from: Ministry of Education Singapore: New 'A' Level Curriculum 2006 (archive.org)

H1 or H2, they do not study both. In contrast, H2 is a requirement to study H3, and students cannot offer H3 without H2. H3 is designed to build on the content of H2 and offers diverse learning opportunities for in-depth study. However, not all subjects are offered at H1, H2 and H3 levels – the table below includes the levels offered per subject area according to the 2023 SGA syllabuses:

Table 8: SGA Subjects Offered at three levels (H1, H2 & H3) of GCE A Level[53]

Discipline	Subject	H1	H2	H3
English Language	English Language and Linguistics		X	
	General Paper (GP)	X		
	Knowledge and Inquiry (KI)		X	
	Project Work	X		
Mother Tongue Languages	Chinese B+	X		
	Chinese Language	X		
	Chinese Translation		X	
	Chinese Language and Literature		X	X
	China Studies in Chinese		X	
	Malay B+	X		
	Malay Language	X		
	Malay Language and Literature		X	X
	Tamil B+	X		
	Tamil Language	X		
	Tamil Language & Literature		X	X
3rd Languages	Bengali	X		
	Gujarati	X		
	Hindi	X		
	French	X	X	
	German	X	X	
	Japanese	X	X	
	Panjabi	X		
	Urdu	X		
	Spanish		X	
Mathematics	Pre-University Mathematics	X	X	X
Sciences	Computing		X	
	Biology	X	X	X
	Chemistry	X	X	X
	Physics	X	X	X
Humanities and the arts	China Studies in English	X	X	
	Commerce		X	
	Economics	X	X	X
	Management of Business		X	
	Principles of accounting		X	
	Geography	X	X	X
	History	X	X	X
	Literature in English	X	X	X
	Theatre Studies and Drama		X	
	Art	X	X	X
	Music		X	X
	Literature in English		X	X
Life skills	Physical Education	-	-	-
	Philosophy of Character and Citizenship	-	-	-
	Values in Action	-	-	-

[53] SEAB. (2022). *A Level Syllabuses Examined in 2023.* Available from: www.seab.gov.sg/home/examinations/gce-A Level/A Level-syllabuses-examined-for-school-candidates-2023; MOE, Singapore. (2022). *A Level curriculum and subject syllabuses.*

	Co-Curriculum Activities	-	-	-

Unit requirements

In order to sit their GCE A Level examinations, students must complete 10 to 12 academic units (AU) of study, where:

- each H1 subject carries 1 AU
- each H2 subject carries 2 AU
- each H3 subject carries 1 AU (as it is taken in addition to the H2 subject); and
- the total number of AU should not exceed 12.[54]

In practice, this typically means that students take:

- at least four content-based subjects, typically:
  - three H2 content-based subjects
  - one H1 content-based subject, as well as H1 Mother Tongue Language (MTL) (or MT syllabus B in some circumstances[55])
- H1 General Paper (GP), or H2 Knowledge and Inquiry (KI) in lieu – the latter counting as a fourth H2 subject.[56]
- H1 Project Work (PW).

Moreover, at least one of the student's chosen subjects needs to be from a contrasting discipline to the others, to ensure a 'broad educational experience'.[57] In the context of the SGA, a contrasting discipline is a subject that belongs to the opposite subject group to the subject group a student is specialising in – i.e. a subject from the 'Humanities and the Arts' group if the student is taking mostly 'Mathematics and Sciences' courses, and vice versa. These contrasting subjects can be taken at either H1 or H2. Notably, the Knowledge and Inquiry subject counts as a contrasting subject regardless of subject group. Moreover, while H1 mother tongue language and H1 foreign language do not count as contrasting subjects, H2 mother tongue language and literature and H2 foreign language count as contrasting subjects to the 'Mathematics and Science' group.[58]

It should be noted that, when it comes to obtaining academic units for university admission, only courses from the knowledge skills and subject-based knowledge groups count towards the General Certificate of Education (GCE) – the certificate typically used for access to higher education.

Assessment

The successful studying of the SGA curriculum culminates with the Singapore GCE A Level, an annual national examination that is jointly conducted by the MOE, SEAB and Cambridge

[54] SEAB. (2022). *2022 Singapore-Cambridge GCE A Level Examinations - Registration Information for School Candidates.* Available from: 2022 Instructions For School Candidates (seab.gov.sg)
[55] Students should sit the Year-End mother tongue syllabus B examination if they did not obtain at least D7 in GCE O Level MTL or take MTL Syllabus B at GCE O Level.
[56] SEAB. (2022). *2022 Singapore-Cambridge GCE A Level Examinations - Registration Information for School Candidates.* http://www.seab.gov.sg/docs/default-source/schooregistrationinformation/2022_gcealevel_registration_information_for_school_candidates.pdf
[57] Ministry of Education, Singapore. (2022). *Post-secondary Education Booklet*.
[58] Ibid.

Assessment International and is taken by school students and private candidates.[59] All GCE A Level examinations are taken at the end of pre-university education in a single sitting, save for the following exceptions:

- One H1 content-based subject may be sat at the end of the penultimate year of pre-university study (but not again in the final year).
- H1 MTL may be sat at the end of the penultimate year of pre-university study and again mid-way through the final year if the student is resitting.
- Project Work is examined at the end of the penultimate year of pre-university study only.[60]

Most subjects have written examinations that assume various forms, including: structured questions, essay-based questions, and multiple-choice questions.[61]

In terms of grading, the papers are graded differently as illustrated in table below. For instance, the H1 and H2 papers are graded based on an alphabetical scale ranging from A to E. A is the highest score and E is the lowest score; grade S is a sub-pass and U (unclassified) is a fail grade. H3 papers are graded with a Distinction, Merit, Pass or Ungraded (fail).[62]

Table 9: SGA subjects grading[63]

H1 and H2
A
B
C
D
E
S (sub-pass)
Ungraded

H3
Distinction
Merit
Pass
Ungraded

NB: Students achieve a grade for each subject studied at each level.

Students receive examination certificates when they obtain a minimum of a Grade E at either H1 or H2 levels, or a 'Pass' at H3 level. If students are eligible to receive an examination certificate, they will receive the certificate together with their results from their school.[64]

Alternative Awards to the SGA in Singapore's Pre-University Education System

As mentioned above, alternative routes to the SGA curriculum and A Level examinations are offered in the Singaporean pre-university system. Other options that offer technical and vocational education include Polytechnics and the Institute of Technical Education. Polytechnics provide specialised training for technicians and technologists in a variety of fields including business, engineering, IT and sciences. Industry-related work is also offered as part of the curriculum. Moreover, Institute of Technical Education (ITE) qualifications are also

[59] SEAB. (2022). *About GCE A Level.* Available from: www.seab.gov.sg/home/examinations/gce-A Level
[60] Ibid.
[61] SEAB. (2022). *2022 Singapore-Cambridge GCE N(T), N(A), O & A Level Examinations – Examination Rules and Regulations for School Candidates.* Available from: https://www.seab.gov.sg/docs/default-source/schoolexamrulesregulations/gcenoa_level_school_candidates_rules_and_regulations.pdf
[62] SEAB. (2022). *Result Slips and Examination Certificates.* Available from: www.seab.gov.sg/home/examinations/gce-A Level
[63] SEAB. (2022). *Examination rules and regulations.* Available from: 2022 GCE NOA School Candidates Examination Rules and Regulations (seab.gov.sg)
[64] SEAB. (2022). *Result Slips and Examination Certificates.*

offered in a variety of subject areas such as engineering, business, community services, and healthcare. ITE graduates receive a Higher National ITE Certificate (Higher NITEC) or a National ITE Certificate (NITEC).[65]

Philosophy and Curriculum Design Principles

The philosophy of Singapore's curriculum is centred around the development of students' character, mind, and body, promoting a 'holistic education, centred on values, social and emotional well-being and character development'.[66] The curriculum provides learning experiences for students that promote active interaction and connection with others in physical as well as digital settings. This way, the students become mindful of their role within society, and learn to embrace diversity and work with people from different backgrounds.[67]

To maximise learning effectiveness, the MOE adapts appropriate teaching space, approaches, and assessment practices.[68] Positive teacher-student and peer relationships are promoted and encouraged so that there is a culture of care and mutual respect in the classroom. Students are encouraged to take risks, learn from their mistakes and from one another, and be confident in expressing their thoughts and views.[69]

In addition to the curriculum philosophy outlined above, the school system in Singapore is also outcome-based, featuring a number of developmental outcomes known as the 'Desired Outcomes of Education' (DOE). The DOE for post-secondary education focus primarily on helping students become independent and moral citizens, through achieving the following:

- Have moral courage to stand up for what is right.
- Be resilient in the face of adversity.
- Be able to collaborate across cultures and be socially responsible.
- Be innovative and enterprising.
- Be able to think critically and communicate persuasively.
- Be purposeful in pursuit of excellence.
- Pursue a healthy lifestyle and have an appreciation for aesthetics.
- Be proud to be Singaporean and understand Singapore in relation to the world.[70]

Additionally, the MOE also sets out, in its 'Framework of 21st Century Competencies and Student Outcomes', a number of core values, social-emotional competences and 21st century competencies for a globalised world which students should aim to acquire by the end of their education. These include:

Values:

- Respect: Our students demonstrate respect when they believe in their own self-worth and the intrinsic worth of people.
- Responsibility: Our students are responsible when they recognise they have a duty to themselves, their families, community, nation and the world, and fulfil their responsibilities with love and commitment.

[65] MOE, Singapore. (2022). *Post-secondary Education Booklet*.
[66] MOE, Singapore. (2021). *Singapore Curriculum Philosophy.*
[67] Ibid.
[68] Ibid.
[69] Ibid.
[70] MOE, Singapore. (2022). *Desired Outcomes of Education.*

- Resilience: Our students are resilient when they demonstrate emotional strength and persevere in the face of challenges. They show courage, optimism, adaptability and resourcefulness.
- Integrity: Our students demonstrate integrity when they uphold ethical principles and have the moral courage to stand up for what is right.
- Care: Our students are caring when they act with kindness and compassion and contribute to the betterment of the community and the world.
- Harmony: Our students uphold harmony when they promote social cohesion and appreciate the unity and diversity of a multicultural society.

Social-Emotional Competencies:

- Self-Awareness
- Self-Management
- Responsible Decision-Making
- Social Awareness
- Relationship Management

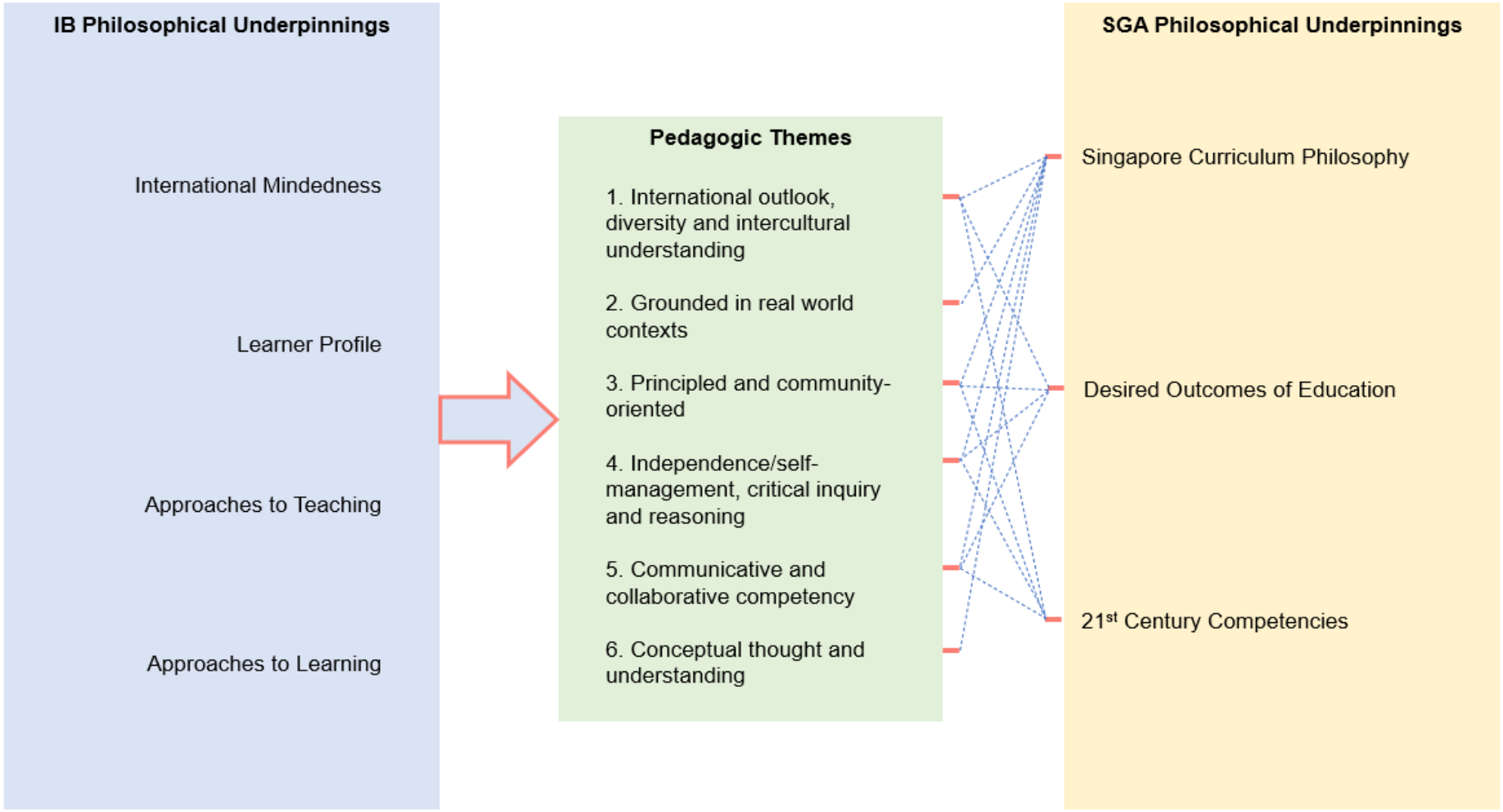
21st Century Competencies for a globalised world

- Civic Literacy, Global Awareness and Cross-Cultural Skills
- Critical and Inventive Thinking
- Communication, Collaboration and Information Skills

All these above have informed the development of the Singaporean pre-university curriculum, and their philosophical alignment with the DP will be explored further in the Philosophical Underpinnings section below.

4.2 Philosophical Underpinnings

Figure 4: Philosophical underpinnings comparative analysis diagram for the DP and SGA



The IB learner profile, which is used across all IB programmes including the DP, outlines 10 attributes that all students should strive towards.[71] Linked to these attributes, there are five categories of approaches to learning skills that all IB programmes aim to develop as well as six categories of approaches to teaching principles. The table in Appendix B presents these qualities of the IB's underpinning philosophies along with the overview used in IB documentation to describe the quality of international-mindedness that also encircles all IB teaching and learning.

The six themes identified within the IB literature have relatively consistent presence across all component parts (learner profile, ATL and international-mindedness). As a result, these themes present a 'boiled-down' version of the DP's philosophical underpinnings.

To identify the level of alignment in relation to the philosophical underpinnings between the DP and the SGA, the project team mapped the philosophical underpinnings of the SGA against six themes extracted from the DP's philosophical underpinnings.

Table 10: Philosophical underpinning themes

Philosophical underpinning themes
• International outlook, diversity, and intercultural understanding • Grounded in real world contexts • Principled and community-oriented • Independence/self-management, critical inquiry, and reasoning • Communicative and collaborative competency • Conceptual thought and understanding

When mapping the six DP themes onto the SGA's 'Curriculum Philosophy',[72] 'Desired Outcomes of Education'[73] and 'Framework for 21st Century Competencies and Student Outcomes',[74] it is apparent that all of the DP themes can be identified, and that most are strongly present in the SGA context. Themes which are especially present are 'principled and community-orientated', 'international outlook, diversity and intercultural understanding', 'communicative and collaborative competency', and 'independence/self-management, critical inquiry, and reasoning'. Themes are typically consistency evidenced across all components of Singapore's curriculum design.

Similar to the DP, SGA students have respect, integrity, care, a sense of responsibility, a sound moral compass, moral courage, and are concerned citizens who care for their families, community, nation, and the world. Furthermore, the SGA philosophical underpinnings demonstrate international-mindedness through valuing each student as an individual and teaching students to appreciate and embrace diversity. Indeed, one of the 21st Century Competencies is 'Civic Literacy, Global Awareness, and Cross-Cultural Skills', and is supported by core values such as that of 'harmony', which intends for students to 'uphold harmony […] and appreciate the unity and diversity of a multicultural society'[75].

[71] International Baccalaureate. (2017). *What is an IB education?*
[72] MOE, Singapore. (2021). *Singapore Curriculum Philosophy.*
[73] MOE, Singapore. (2022). *Desired Outcomes of Education.*
[74] Ibid.
[75] MOE, Singapore. (2021). *21st Century Competencies.*

As with the DP, SGA students are able to confidently and persuasively communicate and learn through collaboration – working harmoniously with people from different backgrounds and being actively contributors in these contexts. Furthermore, through building resilience, working independently, and thinking about their own learning, students are encouraged to be self-directed learners who can take ownership of their learning. The SGA further reinforces this DP theme by developing competencies in self-management, self-awareness, and critical and inventive thinking.

The SGA also promotes conceptual understanding through encouraging active learning and facilitating understanding through making connections between prior learning and new ideas, which in turn enables understanding to be applied to new contexts. Less explicit, but still present, is the theme of 'grounded in real-world contexts', as teaching is enriched with resources from the wider community where appropriate.

However, the components of SGA are more national focus than the DP, as importance is placed on students being able to contribute to Singaporean society – e.g. 'They should also be […] concerned citizens who are rooted to Singapore, have a strong civic consciousness'[76] and also 'proud to be Singaporean and understand Singapore in relation to the world'[77]. This national focus is absent from the DP, given its global essence and focus.

Overall, many of the attributes in the learner profile and principles in IB's approaches to teaching and learning and international-mindedness are reflected in the Singapore Curriculum Philosophy, Desired Outcomes of Education, and 21st Century Competencies.

4.3 Structure

There are six subject groups comprising the DP and students pursuing the Diploma award are normally required to select one subject from each of the six groups.[78] Students usually take three subjects at HL and three at SL. The DP also has three core components which are compulsory and are carried out alongside the grouped subjects. The SGA curriculum categorises content-based subjects into three groups: languages, humanities and the arts, and mathematics and sciences. Students usually study three H2 and one H1 content-based subjects, offering at least one contrasting subject from a different group. The SGA curriculum also has a component focused on 'knowledge skills', from which students must take H1 Project Work, and H1 General Paper or H2 Knowledge and Inquiry. In addition to these, it is also compulsory for students to take at least H1 Mother Tongue Language. Alongside the academic curriculum, it is compulsory for students to take part in non-academic activities and learning which is focused on life skills. These are not formally assessed and do not lead to a certificate but can be considered for university admission. Life skills include co-curriculum activities, character and citizenship education, physical education, and values in action.

The figures below present the subject groups of the DP in comparison with the structure of the subjects in the SGA.

[76] MOE, Singapore. (2021). *Desired Outcomes of Education*.
[77] Ibid.
[78] International Baccalaureate. (2021). *How the Diploma Programme Works*. Available from: https://www.ibo.org/programmes/diploma-programme/what-is-the-dp/how-the-diploma-programme-works/

Figure 5: Structural overview of the DP

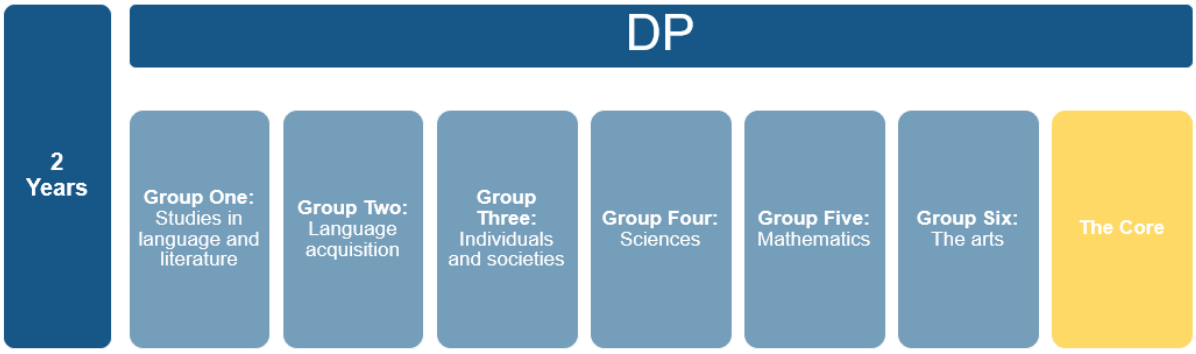
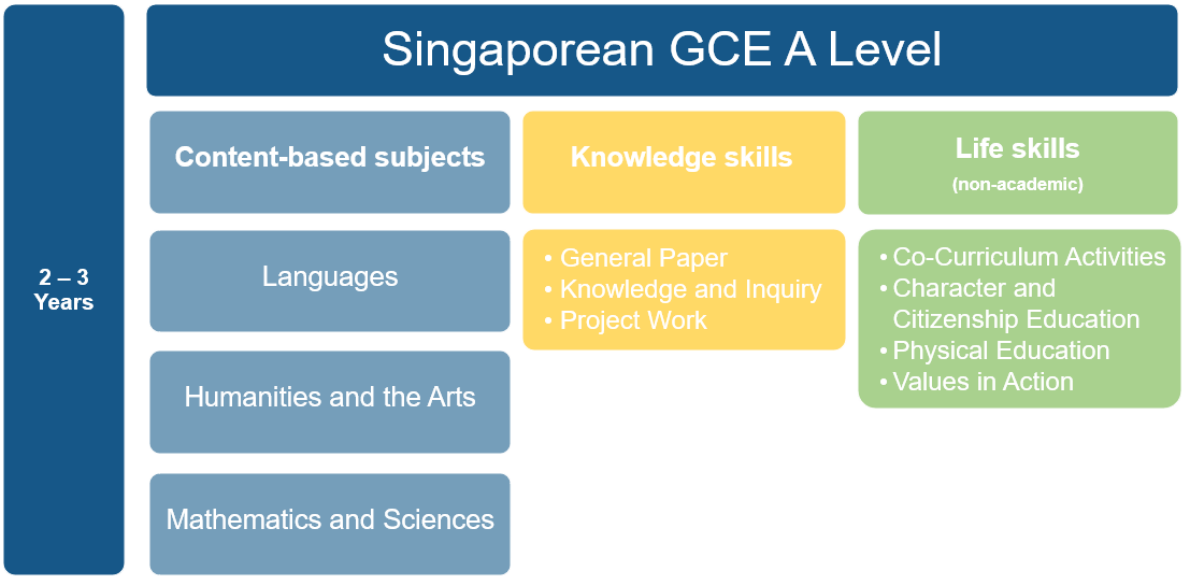


Figure 6: Structural overview of the SGA



There are several similarities in the structure and components of the DP and SGA programmes. Both the DP and SGA categorise their subjects into discipline groups, with corresponding requirements for how students choose subjects. The SGA shares a similar range of disciplines to the DP – including languages, humanities, the arts, mathematics, and sciences – though the categories are broader. Separately to these discipline groups, both the DP and SGA offer compulsory skills-based components, aimed at developing skills of critical thinking, global and local awareness, extended writing, oral presentation, communication, independent research, synthesis and reflection. Knowledge and Inquiry especially correlates to TOK, as it focuses on the nature of knowledge, its construction in different fields, and ethical dimensions – though Singaporean students can study the General Paper instead of this subject. The SGA also has a similar component to CAS, with its non-academic curricula of 'life skills', which includes physical education, co-curricular activities, values in action, and character and citizenship education. Overall, the structure and components of the SGA promote a similarly holistic development to the DP.

The structure and requirements of the levels of study between the DP and SGA are also similar. Indeed, in both programmes students can study subjects at (at least) two levels –

SL/HL for DP and H1/H2 for SGA. Furthermore, both require that students study three subjects at the higher level, demonstrating a similar priority of depth. The number of subjects studied at the lower level is also similar – three for the DP and two (MTL and one other) for the SGA. Though not a requirement, the SGA differs by offering a third level of study, H3, for many of its subjects.

Although the SGA does not follow a strictly baccalaureate-style approach, it does encourage some breadth of study by requiring students to take five different content-based subjects, with at least one subject from a contrasting discipline and a requirement to take H1 MTL. However, the SGA typically has a higher degree of flexibility than the DP, in that, unlike the latter, it does not require students to study one subject from each subject group. Instead, a student may choose to be exposed to breadth, studying subjects from various areas, or they may choose to specialise in one broad area – e.g. the sciences, humanities, or languages – and study up to four subjects from that area.[79] This being said, the DP does offer a non-regular diploma pathway to some students, allowing them to study three sciences and achieve a similar degree of specialisation as that permitted in the SGA.

In terms of programme duration, similarity to the DP depends on the institution within which SGA students complete their pre-university education. If studying at a junior college, the programme will be completed in two years, the same duration as the DP. However, if studying at the millennia institute, the SGA programme will be three years, which allows students more time to prepare for their A Level examinations.[80] Likely as a result of different course lengths, the SGA syllabi do not stipulate the teaching hours for each subject, whereas the DP programme outlines the teaching hours of individual subjects and topics.

4.4 Requirements and Associated Outcomes

There are no formal entrance requirements stipulated for the DP as the IB envisages numerous educational pathways leading to upper secondary education.[81] However, the IB recommends consulting the subject guides prior to enrolment to ensure an adequate understanding of programme expectations.[82] There are also different pathways which can lead to taking the SGA. Students may study O Levels at the end of their secondary education or be on an Integrated Programme that spans both secondary and pre-university education without requiring O Level examinations.[83] Schools such as junior colleges and the millennia institute set out formal entry requirements in the form of admissions criteria. These are based on O Level results, including L1R5 and L1R4 scores for JCs and MIs respectively, as well as grade requirements for specific subjects.[84] Bonus points are also available for attainment in co-curricular activities, language grades, and school affiliation.

In terms of associated outcomes, according to the DP documentation, although the DP is conceived as a preparatory programme for university matriculation and higher education

[79] MOE, Singapore. (2022). *Post-secondary Education Booklet*.
[80] MOE, Singapore. (2022). *Post-secondary Education Booklet*.
[81] International Baccalaureate. (2015). *DP. From principles into practice*. p. 22.
[82] Ibid.
[83] MOE, Singapore. (2022). *Post-secondary Education Booklet*.
[84] MOE, Singapore. (2022). *Joint Admissions Exercise (JAE)*. Available from: (Joint Admissions Exercise (JAE): Admission criteria | MOE

focusing primarily on rigorous academic study, the programme can also prepare students for employment. Similarly, the SGA is designed to prepare students for higher education, whilst also equipping students for a knowledge-based society.

To be awarded an SGA certificate, students need only achieve a grade E in one subject, either H1 or H2, hence this is independent of performance in other areas. In contrast, in order to be awarded a diploma in the DP, students must achieve a minimum pass grade of 3 in all subjects studied. For both programmes, grades are produced for each individual subject.

4.5 Student Learning Pathways

In terms of learning pathways, both programmes include compulsory and optional elements. See the programme overviews in section 4.1 for further details on subject selection. To understand the levels of optionality and potential specialisation in each programme, it is instructive to look at what an individual student would be able to choose in practice. The following diagrams demonstrate the subject options available to an imagined student who knows that they would like to study physics at university after the completion of their upper secondary studies.

Figure 7: DP imagined pathway for a student wishing to study physics at university

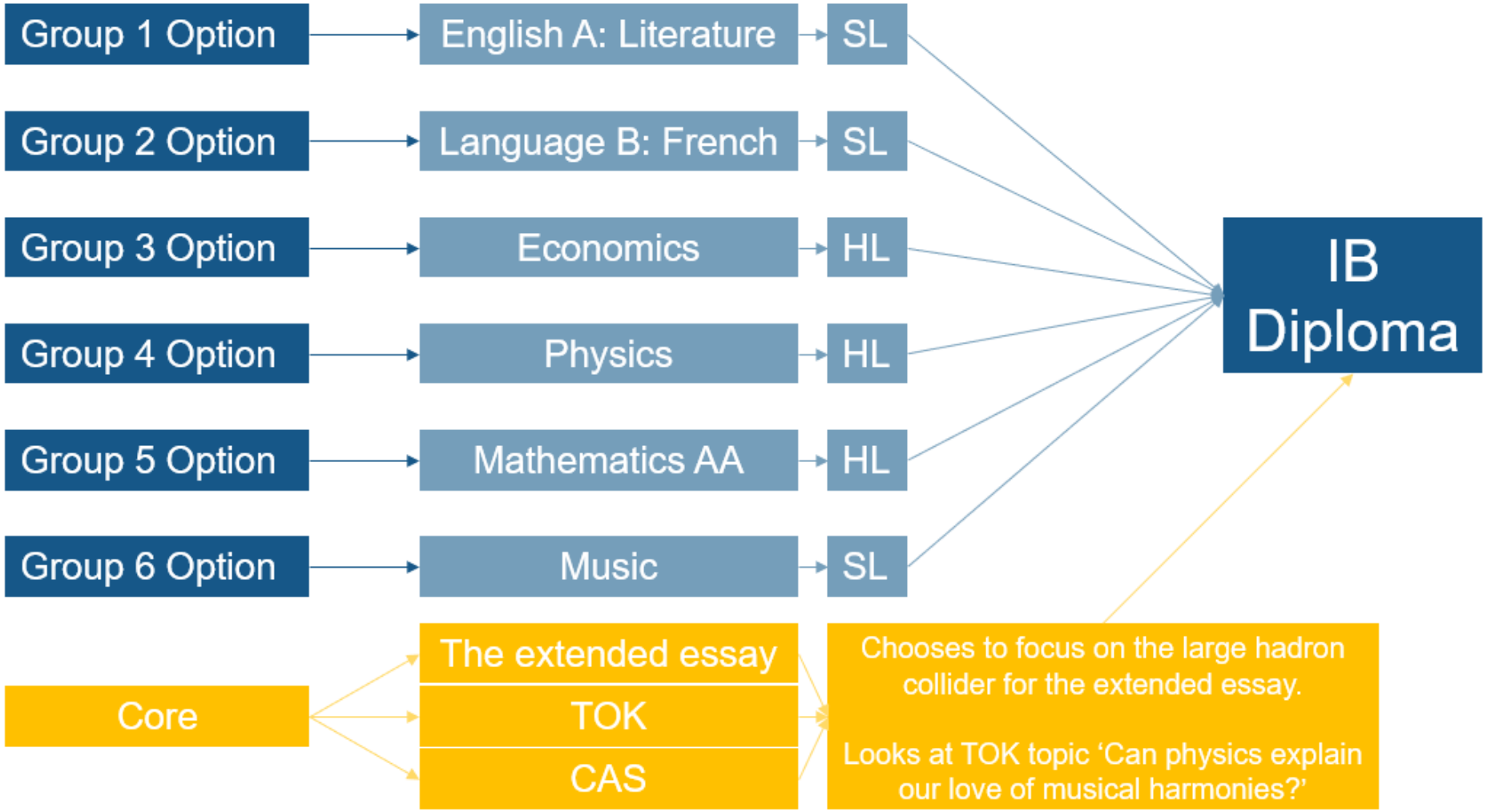
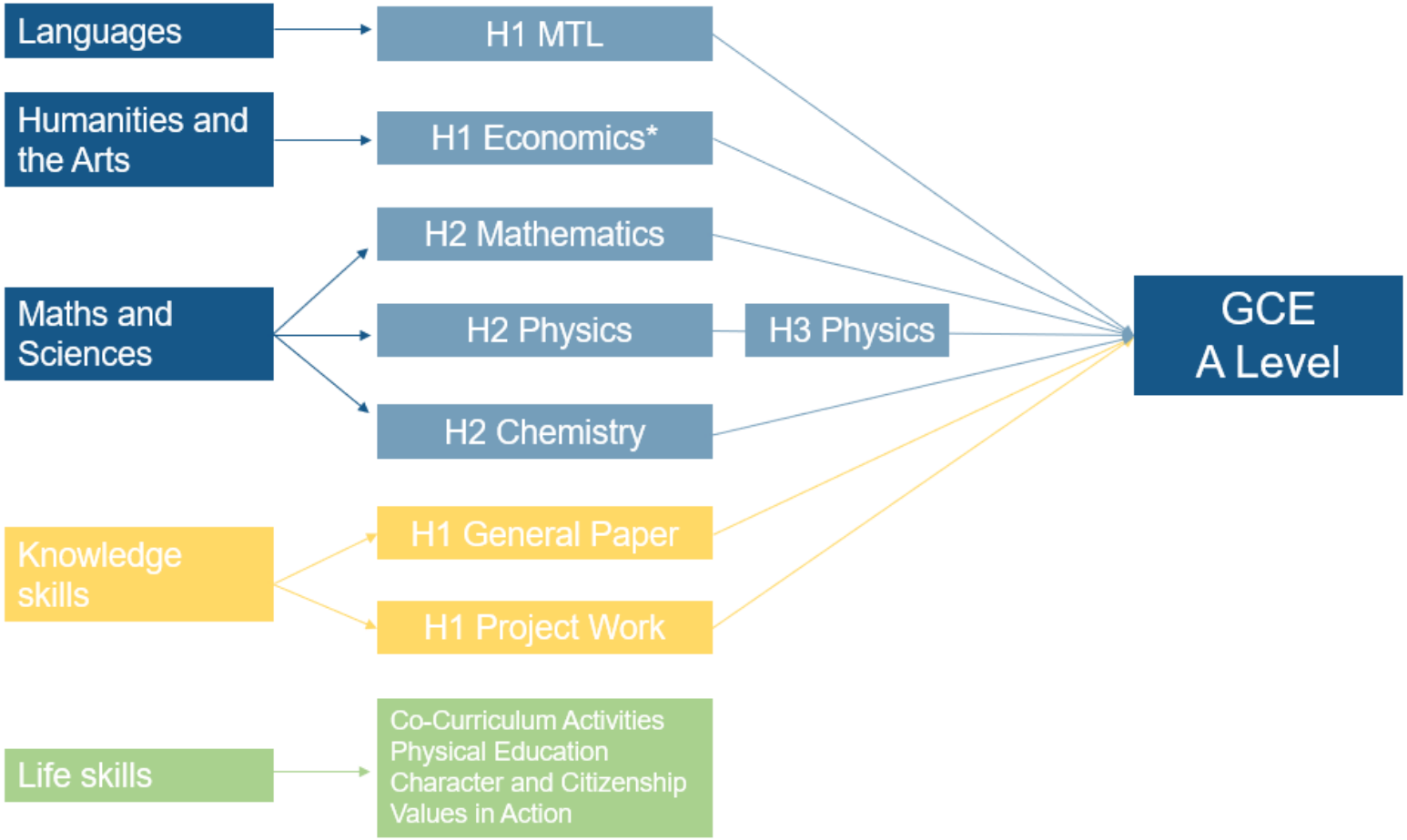


Figure 8: SGA imagined pathway for a student wishing to study physics at university[85]



[85] *Contrasting subject

As can be seen from the diagram, it is possible for SGA students to take a pathway that is very similar to the DP, studying a similar breadth and depth of subjects. The key difference is that, depending on students' choices, pathways may be more specialised in the SGA than the DP. In the DP, learners are required to study six subjects concurrently, typically one from each subject group. For SGA, learners are required to study five subjects (including MTL), with at least one from a contrasting discipline.

Both programmes provide opportunities for students to expand learning in specific subjects of interest – the DP allows up to four subjects to be studied at higher level, as does the SGA. SGA students can also choose to offer an additional H1, or up to two H3 subjects. Both programmes also have flexibility in their requirements to accommodate students' interests. The DP allows students to opt for an additional sciences, individuals and societies, or languages subject, instead of a subject in the arts. For SGA, students can take H2 Knowledge and Inquiry as their contrasting subject and in place of H1 General Paper. Also, instead of H1 MTL, students can study H2 Mother Tongue Language and Literature, which will also count as one of the three H2 content-based subjects.

For SGA students showing particular aptitude and interest, selected junior colleges also offer specialised programmes. On successful completion of these programmes, students will often be awarded a certificate of recognition. Students will need to take a H2, and sometimes a H3, in a relevant subject to be considered for entry. These programmes can include H3 subjects, consideration for other awards, and special programme activities, such as trips, lectures, symposiums, camps, school projects, immersive experiences, and internships. Scholarships are often available for these programmes. The below is a list of specialised programmes:[86]

- Chinese Language Elective Programme (CLEP)
- Bilingual Studies Programme (BSP)
- Malay Language Elective Programme (MLEP)
- Tamil Language Elective Programme (TLEP)
- Humanities Talent Development Programme (HTDP)
- Art Elective Programme (AEP)
- Music Elective Programme (MEP)

There are also H3 subjects which are offered as part of programmes by MOE partners. Below are some examples:[87]

- Humanities and Social Sciences Research (NUS-MOE)
- Game Theory (SMU)
- Science Research (NTU)
- Geopolitics: War & Peace (NUS).

[86] MOE, Singapore. (2022). *Our programmes*. Available from: Programmes for pre-university level | MOE
[87] SEAB. (2022). *Registration Information for School Candidates.*

4.6 Assessment Methods

This section looks at the key features of assessment in both programmes by using a simple table followed by a short textual description of the key similarities and differences.

Table 11: Top level assessment comparisons

	DP	SGA
External assessment	✓	✓
Weighting	Varies by subject	100%
Mathematics	**SL & HL:** 80%	**H1, H2 & H3:** 100%
Sciences	**SL & HL:** 80%	**H1, H2, & H3:** 100%
Methods	Exam (Typically, two-three exam papers per subject)	Exam (Typically one-two written exams for H1, two–four for H2 and one for H3)
Mathematics	**SL:** 2 papers of 90 minutes in duration each, with 80 marks available in each. **HL:** 3 papers with durations of 120, 120, and 60 minutes. Marks available are 110, 110, and 55. **Question Types**: compulsory short-response and extended response questions, incorporating problem solving in HL paper 3.	**H1:** 1 paper, worth 100%, with duration 180 minutes **H2:** two papers, each worth 50%, with duration of 180 minutes each. **H2F:** two papers, each worth 50%, with duration of 180 minutes each. **H3:** 1 paper, worth 100%, with duration 180 minutes **Question Types:** all questions are compulsory and of varying lengths. Questions include application of mathematics to real-world contents.
Sciences	**SL:** 3 papers worth 20%, 40%, and 20% of total weighting, with duration of 45, 75, and 60 minutes each. **HL:** 3 papers worth 20%, 36%, and 24% of total weighting, with duration of 60, 135, and 75 minutes each. **Question Types:** multiple choice, short and extended response, data-based and experiment-based; some optionality in paper 3.	**H1:** 2 papers, worth 33% and 67% of total weighting, with duration of 60 and 120 minutes each respectively. **H2:** 4 papers, worth 15%, 30%, 35%, and 20% of total weighting, with duration of 60, 120, 120, and 150 minutes each. **H3:** 1 paper, worth 100%, 180 minutes in duration for physics, and 150 minutes for chemistry and biology **Question Types:** multiple choice, short structured, longer structured, free response (excluding physics and H1 chemistry), data-based questions, practical-based questions (H2 only). Some optionality in H1 Paper 2, H2 Paper 3 and the H3 Paper.
Internal assessment	✓ (Often used)	✗
Weighting	Varies by subject	N/A
Mathematics	**SL & HL:** 20%	N/A
Sciences	**SL & HL:** 20%	N/A
Methods	Vary by subject, but should follow IB guidance	N/A
Mathematics	**SL & HL:** A 'mathematical exploration' involving a piece of written work for 20 marks.	N/A
Sciences	A practical, individual investigation with 10 hours duration and 6-12 pages of write-up.	N/A

Both programmes use external assessment as the main mode of assessment. For the DP, assessments are marked by IB examiners, while in the case of SGA, assessments are set

and assessed by the Singapore Examinations and Assessment Board (SEAB).[88] Furthermore, in both programmes external assessment can take multiple forms, including written, oral, performance, or in electronic format. Many of the same question types are used by both programmes, including short response, extended response, multiple choice, real-world contexts, and experiment-based questions. In both, optionality is not used frequently, though it is used in some papers. Duration of external assessment is similar between the two programmes, consisting of three hours for lower level and five or more hours for the higher level, though SGA duration sometimes exceeds that of the DP. The largest difference between the two programmes is with regard to internal assessment. Whereas the DP has internally assessed components in its subjects, the SGA does not. Where a subject in the SGA is required to have coursework, independent study, oral presentation, or performance, these components are often submitted to be assessed or moderated externally.

Similar to the DP, the SGA sets out assessment objectives for each of its subjects. See the table below for which of the DP's assessment objectives are present in the SGA comparison subject.

[88] SEAB. (2022). *GCE A Level*. Available from: *https://www.seab.gov.sg/*

Table 12: Comparison of assessment objectives

	AO1	AO2	AO3	AO4	AO5	AO6
DP mathematics subjects	**Knowledge and understanding**	**Problem solving**	**Communication & interpretation**	**Technology**	**Reasoning**	**Inquiry approaches**
SGA mathematics	✓ AO1	✓ AO1/AO2	✓ AO2/AO3	×	✓ AO3	×
DP science subjects	**Demonstrate knowledge**	**Understanding and application**	**Analyse, evaluate, and synthesize**	**Investigation skills**		
SGA H1 and H3 sciences	✓ AO1	✓ AO1/AO2	✓ AO2	×		
SGA H2 sciences	✓ AO1	✓ AO1/AO2	✓ AO2	✓ AO3		

Key:

SGA mathematics AOs

AO1 (all courses) – 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 (all courses) – Formulate real-world problems mathematically, solve the mathematical problems, interpret and evaluate the mathematical solutions in the context of the problems.
AO3 varies slightly for each mathematics course, so the AO3 for each have been listed below:
AO3 (H1) – Reason and communicate mathematically through making deductions and writing mathematical explanations and arguments.
AO3 (H2) – Reason and communicate mathematically through making deductions and writing mathematical explanations, arguments and proofs.
AO3 (H2F) – Reason and communicate mathematically through forming conjectures, making deductions and constructing rigorous mathematical arguments and proofs.
AO3 (H3) – Reason and communicate in precise mathematical language through the writing and evaluation of mathematical proofs and solutions.

SGA sciences AOs

AO1 (all courses) – knowledge and understanding 1. scientific phenomena, facts, laws, definitions, concepts and theories 2. scientific vocabulary, terminology and conventions (including symbols, quantities and units) 3. scientific instruments and apparatus, including techniques of operation and aspects of safety 4. scientific quantities and their determination 5. scientific and technological applications with their social, economic and environmental implications.
AO2 (all courses) – handling, applying and evaluating information to: 1. locate, select, organise, interpret and present information from a variety of sources 2. handle information, distinguishing the relevant from the extraneous 3. manipulate numerical and other data and translate information from one form to another 4. present reasoned explanations for phenomena, patterns, trends and relationships 5. make comparisons that may include the identification of similarities and differences 6. analyse and evaluate information to identify patterns, report trends, draw inferences, report conclusions and construct arguments 7. justify decisions, make predictions and propose

hypotheses 8. apply knowledge, including principles, to novel situations 9. use skills, knowledge and understanding from different areas to solve problems 10. organise and present information, ideas and arguments clearly and coherently, using appropriate language **AO3 (H2 only)** – experimental skills and investigations – 1.follow a detailed set or sequence of instructions and use techniques, apparatus and materials safely and effectively; 2. make, record and present observations and measurements with due regard for precision and accuracy; 3. interpret and evaluate observations and experimental data; 4. identify a problem, devise and plan investigations, select techniques, apparatus and materials; 5. evaluate methods and techniques, and suggest possible improvements.

As can be seen from the table, many of the same skills are prioritised for assessment in both the DP and SGA mathematics and sciences subjects. For mathematics, the SGA also assesses knowledge and understanding, problem solving, reasoning, and communication and interpretation. However, technology and inquiry approaches are not explicitly mentioned in the assessment objectives for SGA mathematics. For sciences, demonstrating knowledge, understanding and application, and analysis, evaluation, and synthesis are assessed by the SGA. However, a difference to the DP is that scientific investigation skills are only explicitly assessed in H2 and not H1.

5. Subject-Level Alignment

This section focuses on answering RQ3 and the sub-questions associated to it, namely:

Table 13: Research question 3

RQ3: To what degree do the subjects align with regard to: 3.1: Content • Topics (i.e. scope of content area, breadth depth) • Learning activities (i.e. difficulty, demand). 3.2: Expected learning outcomes • Knowledge • Competencies (i.e. subject-specific, 21st century competencies).

For each subject area, there is a brief introduction to the subjects being compared, followed by an overview of the findings from the comparative analysis between the DP subjects and the SGA comparison points regarding learning outcomes, content, and demand.

5.1 Mathematics

The following is the list of subjects used in the mathematics subject comparison analysis.

Mathematics: analysis and approaches[89]
Mathematics: analysis and approaches (AA) is a subject option from the mathematics group in the DP curriculum – offered at both SL and HL. This subject is intended for students who are interested in both real and abstract applications of mathematical concepts and enjoy problem solving and generalisation. SL is suitable for students who want to study a good level of mathematics, but not at an advanced level. Therefore, SL prepares students for further study in areas involving mathematical elements, such as geography. HL is suitable for students who want an in-depth study of mathematics and enjoy solving challenging problems. Therefore, HL prepares students for further study in mathematics, as well as other areas with a strong mathematical focus, such as physics and engineering.

Mathematics: applications and interpretation[90]
Mathematics: applications and interpretation (AI) is a subject option from the mathematics group in the DP curriculum – offered at both SL and HL. This subject is intended for students who are interested in exploring more practical applications of mathematics and would enjoy using mathematical models and technology. SL is most suitable for those who want to obtain a good level of knowledge of mathematics, with a focus on real-world applications. Therefore, SL prepares students for further study in areas with some practical mathematics elements, such as biology and business. HL is suitable for students wishing to gain more in-depth knowledge of mathematics, with a focus on real-world situations and the applications of mathematics.

[89] International Baccalaureate. (2019). *Mathematics: analysis and approaches guide*.
[90] International Baccalaureate. (2019). *Mathematics: applications and interpretation guide.*

SGA H1 mathematics[91]
H1 mathematics is designed to provide students with a foundation in mathematics and statistics that will support their business or social sciences studies at university. It is particularly suitable for students without an Additional Mathematics[92] 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.

SGA H2 mathematics[93]
H2 mathematics is designed to prepare students for a range of university courses, including mathematics, sciences and related courses, where a good foundation in mathematics is required. It develops mathematical thinking and reasoning skills that are essential for further learning of mathematics. Through the applications of mathematics, students also develop an appreciation of mathematics and its connections to other disciplines and to the real world. For this level, it is assumed that students have knowledge from Additional Mathematics.

SGA H2 further mathematics[94]
H2 further (H2F) mathematics is designed for students who are mathematically-inclined and who intend to specialise in mathematics, sciences, engineering or disciplines with higher demand on mathematical skills. It extends and expands on the range of mathematics and statistics topics in H2 mathematics and provides these students with a head start in learning a wider range of mathematical methods and tools that are useful for solving more complex problems in mathematics and statistics. H2F is to be offered with H2 as 'double mathematics'.

SGA H3 mathematics[95]
H3 mathematics provides students who intend to pursue mathematics at university with an insight into the practices of a mathematician. It equips students with the knowledge and skills to understand and write mathematical statements, proofs and solutions, and the techniques and results helpful in their work. Students will develop these competencies through proving mathematical results and solving non-routine mathematical problems during their learning. H3 must be offered with H2, from which knowledge of the content is assumed.

5.1.1 Learning Outcomes – Mathematics

For its mathematics learning outcomes, the DP sets out aims and assessment objectives for all subjects within the mathematics subject group – hence the extracted themes are the same for mathematics: analysis and approaches and mathematics applications and interpretation. The learning outcomes for the SGA are represented by the 'mathematics curriculum framework' (MCF), the '21st century competencies' (21CC), and the 'syllabus aims'. The MCF and the 21CC are applicable to all subjects in the curriculum (H1, H2, H2F, and H3), whereas the syllabus aims are unique to each subject. 21CC are to be developed across the curriculum

[91] MOE, Singapore. (2019). *Mathematics Syllabus. Pre-University. Higher 1. Syllabus 8865.* Available from: 2020-pre-university-h1-mathematics.ashx (moe.gov.sg)
[92] Additional Mathematics is an O Level which students can take prior to upper-secondary.
[93] MOE, Singapore (2019). *Mathematics Syllabus. Pre-University. Higher 2. Syllabus 9758.* Available from: 2020-pre-university-h2-mathematics.ashx (moe.gov.sg).
[94] MOE, Singapore (2019). *Mathematics Syllabus. Pre-University. Higher 2. Syllabus 9649.* Available from: 2020-pre-university-h2-further-mathematics.ashx (moe.gov.sg)
[95] MOE, Singapore (2019). *Mathematics Syllabus. Pre-University. Higher 3. Syllabus 9820.* Available from: 2020-pre-university-h3-mathematics.ashx (moe.gov.sg)

but are adapted specifically for mathematics in the subject syllabi. This section will first review the learning outcomes relevant to all subjects, followed by the learning outcomes specific to each subject.

The following summary table demonstrates the learning outcome themes that were extracted from DP mathematics and indicates if and where they were judged to have presence within the learning outcomes of the SGA mathematics curricula.

Table 14: Presence of the DP mathematics subject group learning outcome themes in SGA curricula

Themes extracted from the learning outcomes in the DP mathematics subject group	Presence in the SGA	
1. Being aware of, and engaging with, mathematics in its wider context		Present in the 21CC.
2. Developing learning skills; having a positive and resilient attitude, working both independently and collaboratively, being reflective and evaluating work		Present in the 'metacognition' and 'attitudes' components of the MCF.
3. Using inquiry-based approaches		Absent.
4. Understanding the concepts, principles and nature of mathematics and applying concepts and procedures to a range of contexts		Present in the syllabus aims of H1, H2, H2F, and H3. Also present in the 'concepts', 'attitudes', and 'processes' components of the MCF.
5. Making links and generalisations		Present most strongly in the 'processes' component of the MCF, which encompasses connections and thinking skills. Making connections is also evident across the syllabus aims.
6. Developing critical/creative thinking skills e.g. problem-solving and reasoning		Present in the MCF, of which problem-solving is the center. Also present in the syllabus aims, especially H3.
7. Communicating mathematics clearly and in various forms		Present in the MCF, 21CC, and syllabus aims.
8. Knowing how technology and math influence each other and using technology to develop ideas and solve problems		Present in the 'skills' component of the MCF and the 21CC.

Key:

	This theme is well-evidenced in the learning outcomes of the SGA.		*This theme is partially evidenced in the learning outcomes of the SGA.*		*This theme is not evident in the learning outcomes of the SGA.*

Presence of the DP's Learning Outcome Themes

All subjects:
There is a strong presence of the DP's mathematics learning outcome themes in the syllabi of the SGA. Like the DP, Singapore has a strong emphasis on problem-solving, which is at the core of their MCF. Indeed, developing problem-solving skills is the central focus of the SGA's mathematics curriculum, and is supported by five inter-related components, namely 'concepts', 'skills', 'processes', 'metacognition' and 'attitudes'. These supporting components are also coherent with DP learning outcome themes. For example, 'attitudes and metacognition' contain very similar concepts to the DP, such as the development of interest, enthusiasm, reflective working, perseverance, and confidence in students. Furthermore, 'processes' includes 'reasoning, communication, and connections', which correlate with the respective DP themes of critical thinking skills, communication, and making links and generalisations. More specifically, the MCF expects that students will be able to analyse and construct mathematical arguments; express ideas and arguments logically, accurately, and precisely; and make connections between mathematical concepts, to other subjects, and to real life. Critical thinking skills and making links are further represented by the two other parts of the 'processes' component, which are 'applications and modelling' and 'thinking skills and heuristics'.

In addition, the DP's theme of understanding mathematics is demonstrated through the components of 'concepts' and 'attitudes', whereby it is expected that students will learn a broad range of mathematical concepts and have appreciation of the beauty and power of mathematics. Another theme accounted for is that of technology, as the 'skills' component describes the use of tools, spreadsheets, and software. The last DP theme identified is that of wider contexts, which is found in the 21CC. Indeed, this theme expects that students will have an awareness of, and ability to engage with, the local and global issues around them. The 21CC also reinforce some of the previously mentioned themes by referring to thinking critically, reasoning logically, communicating effectively, using ICT tools, and working individually as well as collaboratively.

Finally, the only DP learning outcome theme not explicitly identified in the MCF or 21CC is that of inquiry-based approaches. SGA syllabi do not specify that students are expected to investigate, make conjectures, or test for validity. However, inquiry-based learning is referred to in the 'Teaching Processes'.

H1 and H2/H2F:
The 'syllabus aims' for H1, H2, and H2F are very similar, with the main difference being the associated outcomes of each – tertiary study into the fields of business and social science for H1 and mathematics, sciences, engineering for H2/H2F. The aims for each syllabus correlate to DP themes through demonstration of some of the previously mentioned expectations such as understanding mathematical concepts, critical thinking skills, making connections, and appreciating the value of mathematics.

H3 only:
The 'syllabus aims' for H3 differ to those for H1, H2, and H2F, though refer to some of the same themes. H3 aims focuses on advanced skills, such as complex problem-solving in non-routine contexts, learning methods of proof, and developing mathematical rigour and

precision. Therefore, these aims reinforce the presence of the DP themes of problem-solving, reasoning, making generalisations, and communicating mathematics.

Other Themes in the SGA

Though the learning outcomes taken from the MCF and the 21CC often relate to a theme extracted from the DP, some have unique elements which are not replicated. These differences are present in the MCF, in the 'metacognition' and 'skills' sections, and two sub-areas of 'processes', specifically 'thinking skills and heuristics', and 'applications and modelling'. For instance, though the DP places emphasis on students reflecting on their work, this differs from metacognition – which goes further to involve the ability to monitor thinking processes and self-regulate learning. Furthermore, 'Thinking skills and heuristics' from the 'processes' component includes different skills, such as identifying patterns, visualization, and heuristics, which are not explicitly mentioned in the DP. Similarly, the 'skills' component includes other considerations to those in the DP, such as spatial visualization. Finally, 'Applications and modelling' from the 'processes' component places a greater focus on modelling than the DP does in its learning outcomes and expects that students will learn to deal with complexity and ambiguity through mathematical modelling.

H3 only:

Though the learning outcomes represented by H3's syllabus aims correlate with the DP's themes of critical thinking skills and communication, they place higher emphasis on the advanced skills within these themes. This can be partially attributed to SGA giving level-specific outcomes, which the DP does not do. That said, H3 has a higher focus on readiness for university-level mathematics than the DP, meaning that skills such as mathematical rigour and methods of proof will have a stronger emphasis.

Summary

Overall, there is a high degree of alignment between the learning outcomes of the DP's mathematics subjects and the SGA's. Nearly all the DP's themes are well-evidenced in the SGA learning outcomes, with the exception of inquiry-based approaches – though these can be found in the 'Teaching Processes'. Generally, the outcomes in the SGA have a higher level of detail than the DP's, especially with the inclusion of course-specific 'syllabus aims'. Partially due to the detailed nature of SGAs outcomes, a slightly greater number of skills are included. However, metacognition skills and some of H3's advanced skills, such as mathematical rigour, do have more emphasis than in the SGA than the DP.

5.1.2 Content – Mathematics

This section compares and contrasts the content of the DP and SGA curricula falling within the category of mathematics. In order to support visual comparison at-a-glance, the DP and SGA mathematics curricula are presented below in diagrams which show the key topics and sub-topics included in each.

Figure 9: DP mathematics: analysis and approaches content visualiser

	Standard level topics	Additional higher level topics
Topic 1 Number and algebra	1.1 Standard form; 1.2 Arithmetic sequences and series; 1.3 Geometric sequences and series; 1.4 Financial applications and geometric sequences and series; 1.5 Integer exponents and intro to logarithms; 1.6 Simple proof; 1.7 Rational exponents and laws of logarithms; 1.8 Sum of infinite convergent geometric sequences; 1.9 Binomial theorem (natural number)	1.10 Counting principles and extended binomial theorem; 1.11 Partial fractions; 1.12 Complex numbers intro; 1.13 Polar and Euler form; 1.14 Complex roots, De Moivre's theorem and powers/roots of complex numbers; 1.15 Proof by counter example, contradiction, and induction; 1.16 Solutions of systems of linear equations
Topic 2 Functions	2.1 Gradients and equations of straight lines; 2.2 Intro to functions; 2.3 Graphing functions; 2.4 Key features of graphs; 2.5 Composite, identity, and inverse functions; 2.6 Quadratic functions; 2.7 Solving quadratic equations and inequalities & the discriminant; 2.8 Reciprocal and rational functions; 2.9 Exponential and logarithmic functions; 2.10 Graphical and analytical solutions; 2.11 Transformations	2.12 Polynomial functions; 2.13 Harder rational functions; 2.14 Odd, even, and inverse functions; 2.15 Graphical and analytical solutions of inequalities; 2.16 Further graphs, including modulus and solutions
Topic 3 Geometry and trigonometry	3.1 Geometry recap; 3.2 Trigonometry recap; 3.3 Applications and diagrams; 3.4 Circles and radians; 3.5 Definitions, exact values, and sine rule for ambiguous case; 3.6 Identities and relationships; 3.7 Functions and transformations of sin, cos, and tan; 3.8 Solving trigonometric equations graphically and analytically	3.9 Reciprocal trigonometric ratios, identities, and inverse functions; 3.10 Compound angle identities and double angle for tan; 3.11 Symmetry properties; 3.12 Intro to vectors; 3.13 Scalar product and application; 3.14 Vector equation of a line and application; 3.15 Coincident, parallel, skew, and intersecting lines; 3.16 Cross product of vectors; 3.17 Planes; 3.18 Intersections and angles (planes)
Topic 4 Statistics and probability	4.1 Sampling; 4.2 Presenting data (tables, histograms, cumulative freq.); 4.3 Measures of central tendency and dispersion; 4.4 Correlation and regression line; 4.5 Intro to probability; 4.6 Diagrams, conditional probability, combined or independent events; 4.7 Discrete random variables; 4.8 Binomial distribution; 4.9 Normal distribution; 4.10 Equation of regression line of x on y; 4.11 Formulae for conditional probabilities and independent events; 4.12 Standardisation of normal variables (z-values)	4.13 Bayes' theorem; 4.14 Continuous random variables
Topic 5 Calculus	5.1 Intro to limits and derivatives; 5.2 Increasing and decreasing functions; 5.3 Derivative of $f(x)=ax^n$; 5.4 Tangents and normal; 5.5 Definite integrals; 5.6 More derivatives and use of product, chain, and quotient rules; 5.7 The second derivative; 5.8 Maximum, minimum and inflection points, and optimization; 5.9 Kinematic problems; 5.10 Indefinite integrals and integration by inspection and substitution; 5.11 Definite integrals and area of a curve	5.12 Continuity, differentiability, limits, and higher derivatives; 5.13 Evaluation of limits and L'hopitals rule; 5.14 Implicit differentiation; 5.15 Further derivatives and indefinite integrals; 5.16 Integration by substitution and by parts; 5.17 Volumes of revolution; 5.18 First order differential equations; 5.19 Maclaurin series
The toolkit and mathematical exploration	The exploration is a piece of written work that involves investigating an area of mathematics.	

Figure 10: DP mathematics: applications and interpretation content visualiser

	Standard level topics	Additional higher level topics
Topic 1 Number and algebra	1.1 Standard form; 1.2 Arithmetic sequences and series; 1.3 Geometric sequences and series; 1.4 Financial applications of geometric sequences and series; 1.5 Integer exponents and intro to logarithms; 1.6 Approximation, estimation, bounds and errors; 1.7 Amortization and annuities using technology; 1.8 Using technology to solve systems of equations and polynomials	1.9 Laws of logarithms; 1.10 Rational exponents; 1.11 The sum of infinite geometric sequences; 1.12 Complex numbers; 1.13 Euler and Polar form; 1.14 Matrices; 1.15 Eigenvalues and eigenvectors
Topic 2 Functions	2.1 Gradients and equations of straight lines; 2.2 Intro to functions; 2.3 Graphing functions; 2.4 Key features of graphs; 2.5 Modelling with functions; 2.6 Modelling skills	2.7 Composite and inverse functions; 2.8 Transformations; 2.9 Modelling further functions; 2.10 Using logarithms to scale numbers and linearize data
Topic 3 Geometry and trigonometry	3.1 Geometry recap; 3.2 Trigonometry recap; 3.3 Applications and diagrams; 3.4 Circles, sectors, and arcs; 3.5 Equations of perpendicular bisectors; 3.6 Voronoi diagrams	3.7 Radians; 3.8 Sin, Cos, Tan definitions, and Pythagorean identity; 3.9 Matrix transformations; 3.10 Vectors introduction and notation; 3.11 Vector equation of a line; 3.12 Vector application to kinematics; 3.13 Scalar and cross product; 3.14 Graph theory and simple, directed and subgraphs; 3.15 Adjacency matrices and weighted adjacency tables; 3.16 Decision math
Topic 4 Statistics and probability	4.1 Sampling; 4.2 Presenting data (tables, histograms, cumulative freq.); 4.3 Measures of central tendency and dispersion; 4.4 Correlation and regression line; 4.5 Intro to probability; 4.6 Diagrams, conditional probability, combined or independent events; 4.7 Discrete random variables; 4.8 Binomial distribution; 4.9 Normal distribution; 4.10 Spearman's rank; 4.11 Hypothesis testing, chi-squared and t-tests	4.12 Collecting and organising data and testing for reliability and validity; 4.13 Regression, residuals, coefficient of determination; 4.14 Linear transformations, linear combinations, unbiased estimations; 4.15 Central Limit theorem; 4.16 Confidence Intervals; 4.17 Poisson Distribution; 4.18 Further hypothesis testing; 4.19 Transition matrices and Markov chains
Topic 5 Calculus	5.1 Intro to limits and derivatives; 5.2 Increasing and decreasing functions; 5.3 Derivative of $f(x)=ax^n$; 5.4 Tangents and normal; 5.5 Definite integrals; 5.6 Maximum and minimum points; 5.7 Optimisation; 5.8 Area using trapezoidal rule	5.9 More derivatives and the chain, product, and quotient rule; 5.10 Second derivatives; 5.11 Finding further integrals and integration by inspection and substitution; 5.12 Area of a region and volumes of revolution; 5.13 Kinematic problems; 5.14 Differential equations; 5.15 Slope fields and their diagrams; 5.16 Euler's method and numerical solutions to differential equations and coupled systems; 5.17 Phase portraits; 5.18 Simple second order differential equations
The toolkit and mathematical exploration	The exploration is a piece of written work that involves investigating an area of mathematics.	

Figure 11: SGA mathematics content visualiser for H1, H2, H2F, and H3

H1 mathematics	**Section A: Pure mathematics**	**1 Functions and graphs**	1.1 Exponential and logarithmic functions and graphing techniques	1.2 Equations and inequalities				
		2 Calculus	2.1 Differentiation	2.2 Integration				
	Section B: Probability and statistics	**3 Probability and statistics**	3.1 Probability	3.2 Binomial distribution	3.3 Normal distribution	3.4 Sampling	3.5 Hypothesis testing	3.6 Correlation and linear regression
H2 mathematics	**Section A: Pure mathematics**	**1 Functions and graphs**	1.1 Functions	1.2 Graphs and transformations	1.3 Equations and inequalities			
		2 Sequences and series	2.1 Sequences and series					
		3 Vectors	3.1 Basics properties of vectors in two- and three-dimensions	3.2 Scalar and vector products in vectors	3.3 Three-dimensional vector geometry			
		4 Introduction to complex numbers	4.1 Complex numbers in cartesian form	4.2 Complex numbers and expressed in polar form				
		5 Calculus	5.1 Differentiation	5.2 Maclaurin series	5.3 Integration techniques	5.4 Definite integrals	5.5 Differential equations	
	Section B: Probability and statistics	**6 Probability and statistics**	6.1 Probability	6.2 Discrete random variables	6.3 Normal distribution	6.4 Sampling	6.5 Hypothesis testing	6.6 Correlation and linear regression
H2 further mathematics	**Section A: Pure mathematics**	**1 Algebra and calculus**	1.1 Mathematical inductions	1.2 Complex numbers	1.3 Polar coordinates	1.4 Conic sections	1.5 Applications and definite integrals	1.6 Differential equations
		2 Discrete mathematics, matrices and numerical methods	2.1 Recurrence relations	2.2 Matrices and linear spaces	2.3 Numerical methods			

	Section B: Probability and statistics	**3 Probability and statistics**	3.1 Discrete random variables	3.2 Continuous random variables	3.3 Hypothesis testing and confidence intervals	3.4 Non-parametric tests
H3 mathematics	*Students learn to prove properties and results, and solve non-routine problems involving:* **(1) H2 mathematics content areas** **(a) Functions,** e.g. graphs, symmetries, derivatives, integrals, differential equations, limiting behaviours, bounds **(b) Sequences and series,** e.g. general terms, sum, limiting behaviours, bounds *The examples in (a) and (b) illustrate some types of problems that are based on content in H2 mathematics.* **(2) Additional content areas** **(a) Inequalities:** AM-GM inequality, Cauchy-Schwarz inequality, triangle inequality **(b) Numbers:** primes, coprimes, divisibility, greatest common divisor, division algorithm, congruences and modular arithmetic **(c) Counting:** distribution problems, Stirling numbers of the second kind, recurrence equations, bijection principle, principle of inclusion and exclusion. *The above define the expected scope of content knowledge that may be assessed.* *Notwithstanding the content areas defined above, students will also prove results and solve problems outside these defined areas or at the intersection of two or more such areas using their ability to understand and apply given definitions or results.*					

Structure

Like the DP, Singapore offers different levels to students studying mathematics – H1, H2, H2F, and H3. The content in each increases in complexity, with H2, H2F, and H3 all aiming towards the higher-end of upper-secondary mathematics and H1 offering a more basic, though still substantial, coverage of upper-secondary topics. Therefore, for students who are able to study mathematics at a higher level, it can be noted that SGA offers slightly more options (H2, H2F, and H3) than the DP, which offers AA HL or AI HL. SGA students can also study a larger number of mathematics subjects, as they can take H2, H2F, and H3 (or H2 and one other), whereas DP students may only study one HL subject, as they cannot take both AA and AI. Moreover, Singapore offers a subject (H3) which is dedicated to developing skills and methods for students who are specifically intending to study mathematics at university. Though the DP aims to prepare students for university study, H3 more closely resembles some of the material and skills students will use in higher education mathematics. In terms of subjects that take an applied focus, the SGA somewhat offers this in the form of H1. H1 assessment contains 40% pure mathematics and 60% applied mathematics (statistics and probability), thus being similar to AI in that statistics and probability is the largest topic area. However, unlike the DP, an 'applied-focus' subject is not offered at a higher level; instead, the higher levels incorporate some applied content – except for H3, which focuses primarily on abstract concepts and methods of proof.

With regard to main topics, there are strong similarities between the DP and Singapore's subjects. Just as 'Number and algebra', 'Functions', 'Geometry and trigonometry', 'Statistics and probability', and 'Calculus' will be taken by all students studying the DP, the topics of 'Functions', 'Calculus', and 'Statistics and probability' will be covered by all students taking SGA mathematics – regardless of the level chosen. Interestingly, however, geometry and trigonometry content does not feature as a main topic in the SGA, as most of this content is covered in prior learning (GCE Mathematics O Level and GCE Additional Mathematics O Level) – instead, 'Vectors' is a main topic in H2. Also, unlike the DP, though all students will study the main topics described above, there are other topics which vary depending on the level; they are not the same for all subjects as they are in the DP.

Another key difference is the way in which content follows on from previous studies. Whereas additional higher level (AHL) content follows on from SL in the DP HL, H2 does not follow on from H1 in the SGA. Instead, H1 content directly follows on from GCE O Level Mathematics and H2 content directly follows on from GCE O Level Additional Mathematics; therefore, either H1 *or* H2 is studied, not both. However, students must study H2 to study H2F and H3.

Finally, whereas H1, H2, and H2F break content down into main topics and sub-topics akin to the DP structure, H3 takes a different approach. The content detail for H3 is less specific and focuses on the skills of mathematical communication, advanced problem-solving, and methods of proof, rather than specific topics. Nevertheless, the syllabus does give examples of the areas to which mathematical proofs, results, and advanced problem-solving will relate.

Content Alignment

See the table below for a simplified summary of the extent to which SGA mathematics aligns with the main topics of the DP's subjects. As indicated in the content structure section above, various topics are not present in H1, H2, H2F, and H3 themselves, but are featured in the content of O Levels, which, although not strict pre-requisites, contain content that is regarded

as assumed knowledge by the SGA subjects. H1 and H2 assume knowledge from O Level Mathematics and H2 also assumes knowledge from O Level Additional Mathematics. The A Level syllabi is then designed to follow on from the content of O Level. The analysis has taken this into account and carries forward the O Level alignments to represent the cumulative content learnt by students studying the SGA. As Additional Mathematics contains a significant amount of overlapping content with the DP, it has been included in the table. The topics where prior learning has impacted alignment significantly will be noted in the analysis.

Figure 12: Summary of the content alignment SGA has with the main topics in AA

		Prior learning	Presence in SGA mathematics			
AA topics		Additional Mathematics	H1	H2	H2F	H3
SL	1. Number and algebra					
	2. Functions					
	3. Geometry and trigonometry					
	4. Statistics and probability					
	5. Calculus					
AHL	1. Number and algebra					
	2. Functions					
	3. Geometry and trigonometry					
	4. Statistics and probability					
	5. Calculus					

Figure 13: Summary of the content alignment the SGA has with the main topics in AI

		Prior learning	Presence in SGA mathematics			
AI topics		Additional Mathematics	H1	H2	H2F	H3
SL	1. Number and algebra					
	2. Functions					
	3. Geometry and trigonometry					
	4. Statistics and probability					
	5. Calculus					

AHL	1. Number and algebra					
	2. Functions					
	3. Geometry and trigonometry					
	4. Statistics and probability					
	5. Calculus					

Key:

	Strong presence of this topic in the SGA.		*Partial presence of this topic in the SGA.*		*Little or no presence of this topic in the SGA.*	N/A	*This topic does not exist at the respective level.*

* Where applicable, content alignments found in assumed knowledge or pre-requisite subjects are carried forwards and combined with new alignments to represent the cumulative content covered.

H1 mathematics

Mathematics: analysis and approaches

The mapping of content shows that sub-topic alignments for H1 are usually located in the SL content of AA, to varying degrees depending on the topic. The main topic with the most alignment is that of SL 'Statistics and probability', as H1 covers many similar subtopics, including presenting data, regression and correlation, probabilities, and probability distributions. Following this, H1 has a considerable number of sub-topic alignments with 'Functions' SL, due to inclusion of function notation, graphing of functions, and a range of functions, such as exponential and logarithmic. However, the terms 'domain' and 'range' are excluded, as are transformations and rational, reciprocal, composite, and inverse functions.

H1 also has partial alignment with 'Geometry and trigonometry' SL, due to its inclusion of some basic geometry and trigonometry sub-topics, and the exclusion of trigonometric functions, identities, and equations. Moreover, it can be noted that the sub-topic alignments identified are not in H1 but are carried over from prior learning in O Level Mathematics. There is substantial alignment with 'Calculus' SL, as H1 introduces differentiation and integration. However, sub-topics regarding applications and the second derivative are not included, and other sub-topics have partial alignment due to less coverage (for example, only the chain rule is included).

The SL topic that H1 has the fewest sub-topic alignments with is 'Number and algebra'. Though H1 includes a basic coverage of exponents and logarithms, it does not cover sequences and series. However, there are a few statistical areas covered by H1 which are not included in AA. These are sampling and hypothesis testing, which are topics that appear in AI.

Overall, H1 mostly aligns with AA SL content, particularly in the topics of 'Statistics and probability', 'Calculus', and 'Functions'. Therefore, H1 has similar depth to SL in some topics; however, it has less breadth and is overall smaller in content size than SL. There are no significant alignments with AHL content.

Mathematics: applications and interpretation

The mapping of content shows that the sub-topic alignments for H1 are usually located in the SL content of AI, to varying degrees depending on the topic. A main topic which H1 has strong alignment with is that of 'Calculus' SL, as H1 introduces differentiation and integration, including definite integrals, finding maximum and minimum points, and tangents and normals. Similarly, H1 has strong alignment with 'Statistics and probability' SL due to its inclusion of presenting data, correlation, linear regression, probabilities, probability distributions, and hypothesis testing.

H1 has reasonable alignment with 'Geometry and trigonometry' SL sub-topics; however, these come from prior learning (GCE O Level) and do not include Voronoi diagrams. There is partial alignment with 'Functions' SL due to the graphing of functions. Nevertheless, modelling of functions is not a focus of H1, thus this significantly impacts alignment with this topic. The topic with the least alignment is 'Number and algebra', as sequences and series are not covered in H1.

Overall, H1 mostly aligns with AI SL content, particularly with the topics of 'Calculus' and 'Statistics and probability'. H1 has comparable depth to SL in certain topics, though sometimes differs in its coverage of the topic, and generally is smaller in breadth and overall size. There are occasional sub-topic alignments with AHL content (such as laws of logarithms), though these are generally insignificant.

*Table 15: SGA H1 mathematics content which is not covered in the DP**

Significant content not in AA (only)	Significant content not in AI (only)
• Sampling (sample mean as a random variable, use of the Central Limit Theorem, unbiased estimates) • Hypothesis testing (formulation of hypotheses and testing for a population mean)	• Combinations and permutations
Significant content not in either DP mathematics subject	
N/A	

* Significant content does not include topics which are typically studied *prior* to upper secondary.

H2 mathematics

Mathematics: analysis and approaches

The mapping of content shows that H2 has a considerable number of SL and AHL sub-topic alignments with AA. Firstly, there is strong alignment within 'Geometry and trigonometry' content, as vectors are covered in similar depth and detail in H2. Furthermore, there are sub-topic alignments with trigonometric functions (including reciprocal), trigonometric equations, radians, and trigonometric identities – though it can be noted that these are not in the syllabus of H2 but are covered prior in the O Level Additional Mathematics. There is also strong alignment with the SL and AHL content of 'Functions', as H2 has an equally wide range of functions and includes composite and inverse functions, transformations, analytical solutions, absolute value, and rational functions.

There is also strong alignment with SL, and most AHL, content of 'Calculus', as H2 includes the second derivative, methods of integration, differential equations, and Maclaurin series. Though, again, it can be noted that several of the SL sub-topics alignments arise from prior learning in the Additional Mathematics. Furthermore, the concept of a limit is not introduced in H2, therefore there are some missing sub-topic alignments regarding this, such as evaluation of limits and differentiation from first principles. Again, for 'Number and algebra' there are strong alignments with SL and some AHL content, as H2 covers sequences and series in a similar level of detail, as well as laws of logarithms and rational exponents. For AHL content, counting principles, systems of equations, and complex numbers are present in H2; however, complex numbers are covered in lesser detail than AA and proof by contradiction and induction is not included.

For 'Statistics and probability', there is strong alignment with SL content, as discrete random variables, linear regression, and probability distributions are all included in H2, though there is no AHL content covered, such as continuous random variables. However, there are a few statistical areas covered by H2 which are not included in AA. These are 'Sampling' and 'Hypothesis Testing', which respectively correlate to AHL and SL sub-topics in AI.

Overall, H2 has strong alignment with SL and AHL content, particularly in the topics of 'Geometry and trigonometry' and 'Functions'. Therefore, H2 content exceeds AA SL in depth, and is more comparable to that of AA HL.

Mathematics: applications and interpretation

The mapping of content shows that H2 has strong alignment with AI SL content and generally partial alignment with AHL content. For 'Functions', there is partial alignment with AHL content, as H2 includes transformations and composite and inverse functions but does not include modelling with AHL functions. There is considerable alignment with SL 'Functions' due to modelling with linear, quadratic, exponential, logarithmic, and trigonometric functions being covered in prior learning (GCE O Level Additional Maths).

For 'Number and algebra', H2 has considerable alignment with SL, as sequences and series are covered in similar depth and detail, and financial applications are listed in the 'Applications and Contexts' section of the syllabus. Furthermore, logarithms and exponentials are covered, as are complex numbers (for the most part); however, matrices are only covered in basic detail (from O Level Mathematics) and eigenvalues and eigenvectors are not included. Similarly, there is strong alignment with SL 'Geometry and trigonometry' content and partial alignment with AHL content. In this area, vectors, trigonometric functions, and radians are included, though matrix transformations and graph theory and decision mathematics sub-topics are not. Additionally, H2 has strong alignment with SL 'Calculus' and some AHL content. Indeed, H2 includes the second derivative, area of a region and volumes of revolution, applications to kinematics, and some differential equations. However, slope fields, Euler's Method, and phase portraits are not included. For 'Statistics and probability', there is strong alignment with SL content as correlations and linear regression, probabilities, discrete random variables, probability distributions, and hypothesis testing are all included. Furthermore, there are a few sub-topic alignments with AHL content as H2 covers 'Sampling', though not enough to be considered significant – H2 does not cover non-linear regression, transition matrices, confidence intervals, and has lesser detail in hypothesis testing.

However, there are a few topics which H2 covers in more or different detail to AI – these are vectors, functions, and trigonometric functions, which more closely resemble AA content. Overall, there is strong alignment with SL content and partially strong alignment with AHL (due to the exclusion of some significant topic areas). In terms of depth, H2 content exceeds AI SL and is comparable to AI HL, albeit sometimes covering different advanced content.

*Table 16: SGA H2 mathematics content which is not covered in the DP**

Significant content not in AA (only)	Significant content not in AI (only)
• Sampling (sample mean as a random variable, use of the Central Limit Theorem, unbiased estimates) • Hypothesis testing (formulation of hypotheses and testing for a population mean)	• Solving inequalities • Absolute value • Further three-dimensional vector geometry content (e.g. equations of planes) • Maclaurin series • Further integrals and integration techniques • Permutations and combinations
Significant content not in either DP mathematics subject	
N/A	

* Significant content does not include topics which are typically studied *prior* to upper secondary

H2F mathematics

This subject is taken with H2 and they combine to create double mathematics. All of the alignments found within H2 still apply (see above); therefore, this section will focus on where H2F content strengthens alignments, or covers topics not included in the DP.

Mathematics: analysis and approaches

Topics in H2F which are relevant to AA and strengthen alignment with AHL content are 'Mathematical Induction', 'Complex Numbers', 'Differential Equations', 'Numerical Methods', and 'Continuous Random Variables', which strengthen alignment with 'Number and algebra', 'Calculus', and 'Statistics and probability'. Overall, almost the entire content of AA can be identified in the SGA when combining the content of H2 and H2F.

However, there is a considerable number of H2F topics which are of an advanced level, but not included in AA. These are 'Polar Coordinates', 'Conic Sections', 'Recurrence Relations', 'Matrices and Linear Spaces', 'Discrete Random Variables (Poisson and Geometric)', 'Hypothesis Testing and Confidence Intervals', and 'Non-parametric Tests'. Furthermore, some topics have similarities with AA but are covered in slightly more or different detail, such as 'Numerical Methods', 'Differential Equations', and 'Applications of Definite Integrals'.

Therefore, students taking H2F are likely to encounter a greater breadth and depth of content than those taking AA HL.

Mathematics: applications and interpretation

Topics in H2F which are relevant to AI and strengthen alignment with AHL content are 'Complex Numbers', 'Differential Equations', 'Matrices and Linear Spaces', 'Numerical Methods', 'Discrete Random Variables (Poisson and Geometric)', and 'Hypothesis Testing and Confidence Intervals'. Like AI content, 'Matrices and Linear Spaces' covers eigenvalues/ eigenvectors and matrix transformations, whilst also including the concepts of nullity, rank, basis, independence, and dimension. Overall, H2F strengthens alignment with 'Number and

algebra', 'Statistics and probability', and 'Calculus' – enabling the majority of AI content to be identified in SGA. However, some sub-topics, such as non-linear regression, graph theory, decision mathematics, Markov chains, and phase portraits, are still not present in H2F.

There is a considerable number of H2F topics which are of an advanced level but are not present in AI. These are 'Mathematical Induction', 'Polar Coordinates', 'Conic Sections', 'Recurrence Relations', 'Continuous Random Variables', and 'Non-parametric Tests'. Furthermore, 'Matrices and Linear Spaces', 'Complex Numbers', 'Applications of Definite Integrals', and 'Numerical Methods' all share similarities to AI, though include some additional details and concepts which are not present in the latter.

Overall, students taking H2F are likely to encounter a greater breadth and depth of content than those taking AI HL.

*Table 17: SGA H2F mathematics content which is not covered in the DP**

Significant content not in AA (only)	Significant content not in AI (only)
• Second order differential equations • Matrices • Eigenvalues and eigenvectors • Approximation of solutions of first order differential equations using Euler method • Poisson distribution • Hypothesis testing and confidence intervals (formulation of hypotheses, testing for a population mean using t-test, difference of population means, contingency tables and χ^2 tests of independence and goodness of fit, and confidence intervals for population mean and proportion)	• Mathematical induction • De Moivre's theorem • Continuous random variables (probability density function, mean, and variance)
Significant content not in either DP mathematics subject	
• Complex numbers – small amount of additional content • Polar coordinates • Conic sections • Surface area of revolution • Recurrence relations • Linear spaces – additional content • Numerical methods – small amount of additional content • Geometric distribution • Non-parametric tests (formulation of hypotheses and testing for: a population median using Sign test and identical probability distributions for two sampled populations in a paired difference design using Wilcoxon matched-pair signed rank test)	

*Significant content does not include topics which are typically studied *prior* to upper secondary. Furthermore, content listed in this table is specific to H2F. As H2 is offered alongside H2F, all topics in the H2 table should be considered in addition to the topics in this table.

H3 mathematics

H3 is offered with H2 and gives students who intend to study mathematics at university the opportunity to develop and practice the skills needed. Essentially, this subject aims to introduce students to the practices of a mathematician, including thinking mathematically, applying mathematical rigour to work, advanced problem-solving, and being able to prove

statements and results. This way of working is usually not seen until university; thus, H3 is likely to support students in their first year of higher education.

H3 states that these skills are applied in some areas taken from H2 ('Functions' and 'Sequences and Series') and additional areas ('Inequalities', 'Numbers', and 'Counting'). As part of this, students learn new language (such as converse, theorem, definition, and conditional statements) and new notation (such as set notation, logical connectives, and existential and universal qualifiers). In terms of proof, students will cover a broad range of techniques, such as proof by induction, contradiction, counterexample, and construction. For this reason, and the abstract nature of it, this subject is more akin to AA than to AI. However, H3 goes significantly beyond the AA content regarding proof – as can be seen by the size of the subject and the wider range of areas with which mathematical rigour and proof are applied.

*Table 18: SGA H3 mathematics content which is not covered in the DP**

Significant content not in AA (only)	Significant content not in AI (only)
	• Methods of proof (induction, counterexample, and contradiction) • Further mathematical language
Significant content not in either DP mathematics subject	
Further mathematical properties, results and proofs in the areas below <u>(1) H2 mathematics content areas</u> (a) Functions: graphs, symmetries, derivatives, integrals, differential equations, limiting behaviours, bounds. (b) Sequences and series: general terms, sum, limiting behaviours, bounds. <u>(2) Additional content areas</u> (a) Inequalities: AM-GM inequality, Cauchy-Schwarz inequality, triangle inequality (b) Numbers: primes, coprimes, divisibility, greatest common divisor, division algorithm, congruences and modular arithmetic (c) Counting: distribution problems, Stirling numbers of the second kind, recurrence equations, bijection principle, principle of inclusion and exclusion, pigeonhole principle. The syllabus also states *'Notwithstanding the content areas defined above, students will also prove results and solve problems outside these defined areas or at the intersection of two or more such areas using their ability to understand and apply given definitions or results'.*	

*Significant content does not include topics which are typically studied *prior* to upper secondary. Furthermore, content listed in this table is specific to H3. As H2 is offered alongside H3, all topics in the H2 table should be considered in addition to the topics in this table.

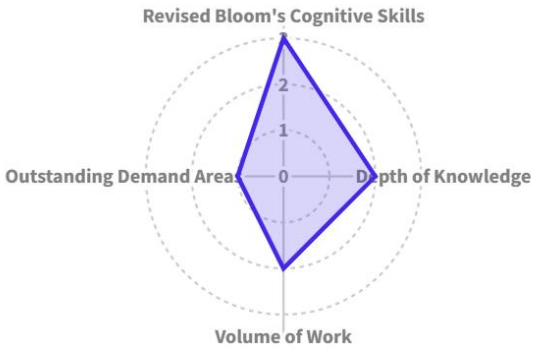
5.1.3 Demand – Mathematics

This section considers the alignment between the DP and SGA mathematics curricula in terms of demand.

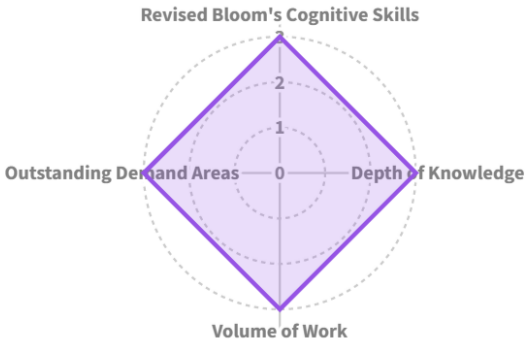
The DP and SGA curricula were analysed using the same demand tool in order to create a demand profile for AA (SL and HL), AI (SL and HL), H1, H2, H2F, and H3. These demand profiles are presented below in the form of radar diagrams, with superimposed diagrams also being featured to enable immediate visual comparison.

Figure 14: Visual representations of subject demand

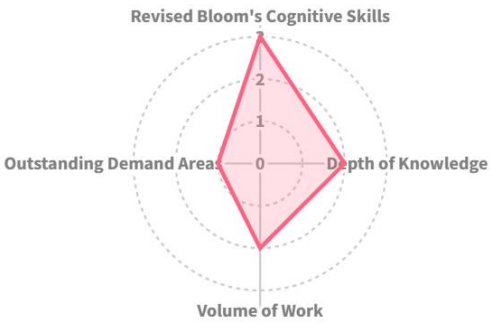
DP mathematics: analysis and approaches SL



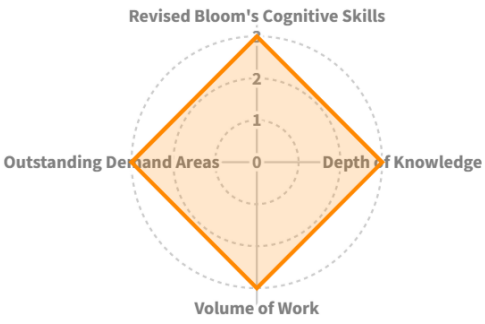
DP mathematics: analysis and approaches HL



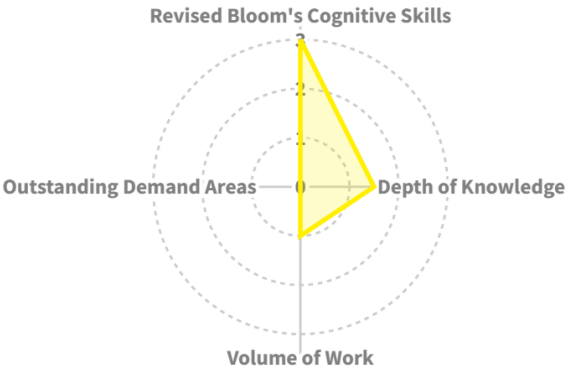
DP mathematics: applications and interpretation SL



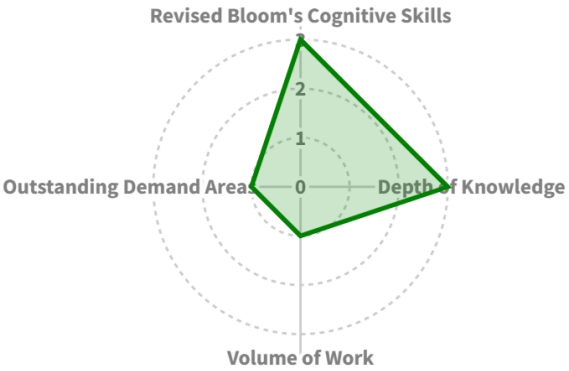
DP mathematics: applications and interpretation HL



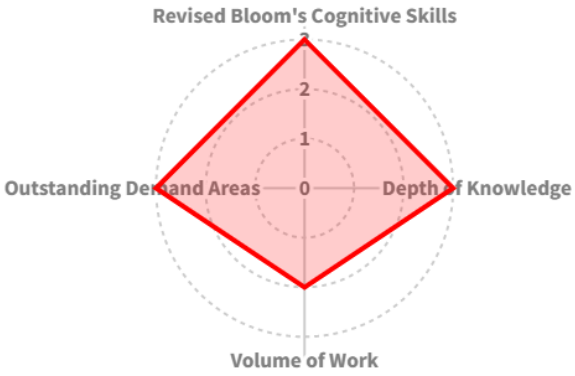
SGA H1 mathematics



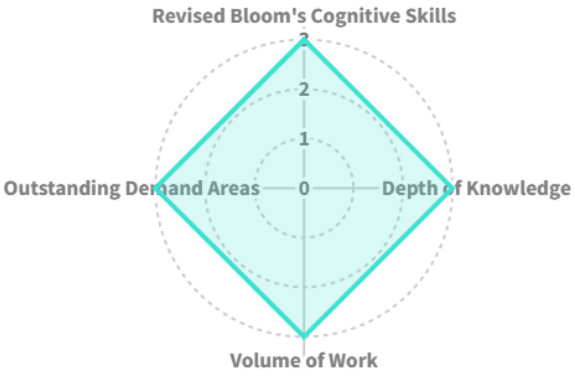
SGA H2 mathematics



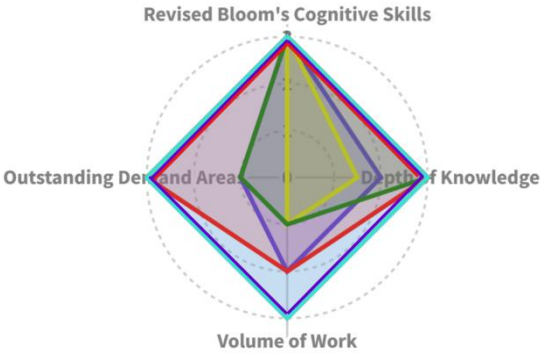
SGA H2 further mathematics



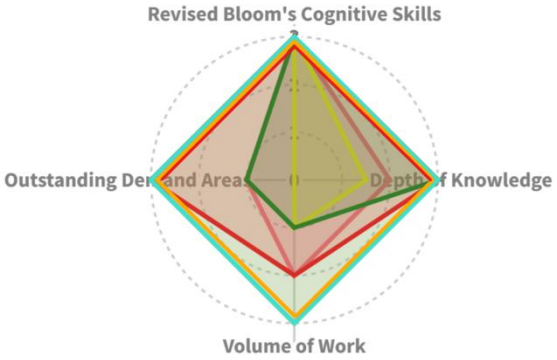
SGA H3 mathematics



DP AA SL/HL and SGA



DP AI SL/HL and SGA



The panel of experts carried out a detailed analysis of each course and reached a consensus on the scores shown in the profiles above. The following points were particularly important within the panel discussion:

- Regarding the scores for **Bloom's Cognitive Skills**:
  - The DP mathematics subject group learning outcomes apply to all subjects hence the scores are the same for AA (SL and HL) and AI (SL and HL). These outcomes were given a score of 3 on the basis that they strongly evidenced the development of critical and creative thinking skills through their focus on reasoning, inquiry-based approaches, reflection, generalisation, unfamiliar contexts, and consideration of wider implications.
  - The learning outcomes of the SGA were drawn from three sources: the syllabus aims, the MCF, and the 21CC. The panel judged that, although the syllabi aims increased in evidence of higher-cognitive skills from H1 to H3, that the skills listed in the MCF and 21CC, which apply to all subjects, were sufficient to justify a score of 3 for all SGA subjects. In these components, skills of reasoning, analysis,

evaluation, critical thinking, generalisation, and metacognition were present. H2F further evidenced this level with references in its syllabus aims to appreciating rigour and abstraction, as did H3 with references to advanced problem-solving skills, rigour in mathematical argument, and writing and evaluation of proofs.

- Regarding the scores for **Depth of Knowledge**:
  - Both DP mathematics subjects at SL were given a score of 2. Both subjects were judged to cover the topics of 'Number and algebra', 'Functions', 'Geometry and trigonometry', 'Statistics and probability', and 'Calculus' in considerable detail, building in complexity and requiring a substantial amount of pre-requisite knowledge. At HL, both DP mathematics subjects were awarded a score of 3 for depth of knowledge. The subjects were judged to cover topics in a high level of detail, with many sub-topics having high complexity and requiring a large amount of pre-requisite knowledge.
  - For SGA, H1 received a score of 1.5 as some topics are studied in considerable depth, in cases comparable to that of SL; however, there was not enough evidence of depth to warrant a score of 2. For the rest of the SGA subjects, a score of 3 was given for depth. H2 required a large amount of pre-requisite knowledge from Additional Mathematics O Level and covered only new content, i.e. prior learning was not re-visited. Furthermore, all topics were studied in a high level of detail – comparable to the DP's HL subjects. Also scoring a 3, H2F focuses on advanced topics, either extending on topics in H2 or introducing new areas which are also explored in depth. Finally, H3 also received a 3 due to the nature of the subject being generally akin to first-year university mathematics, developing practices of a mathematician through focusing on rigor, proof, and advanced problem-solving.

- Regarding the scores for **Volume of Work**:
  - Both DP mathematics subjects at SL were deemed to comprise a moderate-heavy volume of work and were given a score of 2. The panel concluded that the teaching time allotted to cover the different concepts was short (150 hours) but acknowledged that some sub-topics contained basic concepts and recapped prior learning, hence 2 was deemed an appropriate score. For HL, both DP mathematics subjects were considered to have a heavy volume of work, due to the short amount of time allocated (240 hours) and the level of complexity of the content, which combined merited a score of 3.
  - For the SGA, there are difficulties in judging the volume as it varies based on where students will take the qualification. For students attending junior colleges, the programme has a length of two years, whereas in the millennia institute it is three years. Therefore, students in the millennia institute will have a longer period to study their subjects, which impacts the demand of volume. Likely as a result of these differences, the MOE do not publish guidelines for the teaching hours of each subject, therefore scores can only be approximations. For the following scores, it was assumed that the subjects are studied as part of a junior college two-year programme. H1 can be studied over one year, which the panel deemed to be a standard amount of time for the content and requirements of the course. Similarly, H2 was given a score of 1, as two years was deemed a standard amount of time. H2F was raised to a score of 2, due to the majority of time being spent on new and complex topics. Finally, H3 subjects are not required to be taken, therefore they

are studied on top of the regular number of subjects, hence the panel speculated that this would likely increase the volume of work considerably enough to warrant a score of 3 – also considering the advanced nature of a H3 subject.

- Regarding the scores for **Outstanding Areas of Subject Demand**:
  - Both DP mathematics subjects at SL and contained one area of outstanding demand, which was the 'mathematical exploration'. This element of the SL subjects was considered to apply skills typically needed in higher education, such as extended writing and presentation of mathematical concepts, student-led exploration, and academic writing skills. Therefore, a score of 1 was awarded to both SL subjects for the inclusion of this element. In addition to this, both subjects at HL had further areas of outstanding demand. For mathematics: analysis and approaches, some of the identified outstanding areas of demand were proof by induction, complex numbers (De Moivre's theorem), vectors (cross product, equations of planes and intersections), and Maclaurin series. For mathematics: applications and interpretation, some identified areas of outstanding demand were eigenvalues and eigenvectors, nonlinear regression, Markov chains, second order differential equations, slope fields, Euler's method, and phase portraits. Overall, there was a high number of outstanding areas of demand and a score of 3 was awarded to both HL subjects.
  - For SGA subjects, a score of 0 was given to H1, as all content was typical of upper secondary mathematics. For H2, a score of 1 was given, with 3D geometry and calculus containing sub-topics which demonstrated opportunity for stretch. H2F was given a score of 3 as it contained a large number of topics that were beyond the usual scope of upper secondary mathematics, such as matrices and linear spaces, polar coordinates, conic sections, second-order differential equations, and complex numbers (De Moivre's theorem). Finally, H3 was also given a 3 due to requiring students to prove properties and results and solve advanced problems in areas such as sequences and series, functions, numbers, inequalities, and combinatorics.

5.2 Physics

Below is the list of subjects used in the physics subject comparison analysis of the DP with the SGA.

DP physics[96]
Physics is a subject option from the DP sciences subject group, offered at both SL and HL. This subject has content that is common to both SL and HL, as well as AHL content that is featured only at HL. Thus, HL has greater breadth and depth than SL. This subject is intended to prepare students for university courses such as engineering, physics, and others requiring a strong science background. HL is suitable for those intending to pursue further study in an area requiring a strong background in physics.

SGA H1 physics[97]
H1 physics is designed to offer a science education that develops knowledge of core scientific ideas and an understanding of scientific inquiry. This will enable students to make decisions on science-related issues and challenges. H1 physics broadens students' learning and develops their scientific literacy by using real-world contexts; putting less emphasis on handling equipment and carrying out laboratory experiments, and instead focusing on developing scientific knowledge. The aim of the H1 syllabus is to enable students to become scientifically literate consumers who are able to make informed choices concerning science-related issues.

SGA H2 physics[98]
The H2 physics curriculum aims to prepare students for university, work and life by laying a strong foundation of knowledge, skills and attitudes. Upon completing H2 physics, all students will be well-equipped to make informed decisions based on scientific knowledge, but H2 also caters for students who wish to pursue physics further. It gives students a deeper grasp of scientific knowledge and is designed to give students a more coherent and integrated understanding of science rather than a compartmentalised view of knowledge. Application is also a key component of the H2 physics curriculum; students are provided with real-world contexts in order to strengthen their understanding and deepen their scientific knowledge.

SGA H3 physics[99]
H3 physics is designed to build on and extend students' knowledge and understanding gained from H2 physics. Catering to students with a keen interest and strong ability in physics, there is a strong emphasis on independent and self-directed learning, and it aims to provide greater depth and rigour. H3 is designed for students who wish to pursue further studies in physics-related fields by providing them with a greater appreciation of the practice, value and rigour of physics, as well as deepening the knowledge, skills and attitudes gained through the study of H2.

[96] International Baccalaureate. (2023). *Physics guide*.
[97] MOE, Singapore. (2020). *Physics Syllabus. Pre-University Higher 1. Syllabus 8867.* Available from: pre-university-h1-physics-syllabus.ashx (moe.gov.sg)
[98] MOE, Singapore. (2019). *Physics Syllabus. Pre-University Higher 2. Syllabus 9749.* Available from: preuniversity_h2_physics_syllabus.ashx (moe.gov.sg)
[99] MOE, Singapore. (2021). *Physics Syllabus. Pre-University Higher 3. Syllabus 9814.* Available from: 2021-preu-h3-physics.ashx (moe.gov.sg)

5.2.1 Learning Outcomes – Physics

This section compares and contrasts the learning outcomes of curricula falling within the category of physics.

The learning outcome themes for physics were extracted from the aims and assessment objectives of the DP sciences subject group, hence the themes are the same for physics, chemistry, and biology. Similarly, the SGA sets out learning outcomes which apply to all sciences, known as the 'Practices of Science' (PoS). The PoS are split into three components – 'A. Understanding the nature of scientific knowledge', 'B. Demonstrating scientific inquiry skills', and 'C. Relating science and society'. In addition to these, the SGA outlines specific 'syllabus aims', which are specific to the science (physics, chemistry or biology) and the course (H1, H2, or H3). Within each science, H1 and H2 have the same aims, but the aims for H3 are slightly different. H3 builds on and extends knowledge and skills acquired in H2 – the expectation being that students fully grasp the core ideas and learning outcomes of H1 and H2 before deepening and extending this understanding through H3.

The following table demonstrates the learning outcome themes that were extracted from the DP learning outcomes and indicates if and where they were judged to have presence within the learning outcomes of the SGA physics curricula.

Table 19: Presence of the DP sciences subject group learning outcome themes in the SGA physics curricula.

Themes extracted from the learning outcomes of the DP sciences subject group	Presence in the SGA	
1. Conceptual understanding and making connections		Present throughout PoS and aims through descriptions of core ideas that can be applied in a variety of systems, as well as using appropriate models to explain concepts, solve problems and make predictions.
2. Use and application of knowledge, methods, tools, and techniques that characterise science		Present throughout PoS and aims where the SGA mentions understanding the nature of scientific knowledge and demonstrating science inquiry skills.
3. Creativity and critical thinking (problem-solving, analysis, evaluation, synthesis)		Present. Using scientific principles and reasoning to analyse and evaluate, as well as analysing and evaluating systems to generate solutions, is present throughout PoS and aims.
4. Skills for scientific inquiry		Present. Found in PoS in the description of pose scientific questions, plan and conduct investigations and obtain, organise and represent data.
5. Development of technological skills		Absent. Not found in PoS or H1, H2, or H3 aims.

6. Effective collaboration and communication		Partially present. Scientific communication is referenced in PoS in relation to communicating scientific knowledge and findings appropriately, but collaborative competence is not explicitly mentioned.
7. Awareness of global and local problems and the environmental, ethical, cultural, and social impact of science		Present throughout PoS and aims, through recognition that scientific knowledge could be influenced by economic, social, environmental and ethical factors.

Key:

	This theme is well-evidenced in the learning outcomes of the SGA.		*This theme is partially evidenced in the learning outcomes of the SGA.*		*This theme is not evident in the learning outcomes of the SGA.*

Presence of the DP's Learning Outcome Themes

Nearly all the DP's learning outcome themes are present in the aims and PoS for physics H1, H2 and H3. Many statements throughout the PoS imply conceptual understanding and making connections, such as 'use appropriate models to explain concepts, solve problems and make predictions', and 'make decisions based on evaluation of evidence, processes, claims and conclusions'. The aims of H1 and H2 also reflected this theme by outlining the goal to 'develop in students an understanding that a small number of basic principles and core ideas can be applied to explain, analyse and solve problems in a variety of systems in the physical world'.

Demonstrating use and application of knowledge that characterises science is also present throughout the PoS and aims, with explicit reference being present in various PoS statements, including: 'understand that science is an evidence-based, model building enterprise'; 'use appropriate models to explain concepts, solve problems and make predictions'; and 'understand, analyse and evaluate real-world systems as well as generate solutions for problem solving'. H1 and H2 aims also explicitly allude to this in phrases like 'demonstrating science inquiry skills' and, from H3, 'develop[ing] in students their appreciation of the practice, value and rigour of physics as a discipline'.

Creativity and critical thinking can be seen in PoS phrases such as 'understand that the use of both logic and creativity is required in the generation of scientific knowledge', and 'make decisions based on evaluation of evidence, processes, claims and conclusions'. The same goes for problem-solving, which is articulated in the aims in phrases such as 'ideas can be applied to explain, analyse and solve problems' and 'apply relevant concepts and techniques […] to solve problems'.

The application of skills in order to carry out insightful and ethical investigations is briefly covered in the PoS through 'identify scientific problems, observe phenomena and pose scientific questions/hypotheses', 'plan and conduct investigations' and 'obtain, organise and represent data in an appropriate manner'.

Whilst communication is present in the SGA, there is less emphasis on collaborative working. This is evident from only two statements relating to this theme from the PoS: 'recognise that scientific knowledge is generated from consensus within the community of scientists through critical debate and peer review' and 'communicate findings and information using appropriate

language and terminology'. However, despite brief mentions to 'critical debate' and 'peer review', there is no explicit reference to students working collaboratively.

The awareness of local and global problems and ethical, environmental, cultural and social impacts on science also appears throughout the PoS, in statements such as 'science is connected with the natural world', 'recognise that […] problem-solving could be influenced by other considerations such as economic, social, environmental and ethical factors' and 'demonstrate an understanding of the benefits and risks associated with the application of science to society'. Both H1 and H2 aims discuss the importance of this theme through 'providing students with an experience […] for them to become scientifically literate citizens who are well-prepared for the challenges of the 21st century', including 'relating science to society'.

The focus of H1, H2 and H3 aims is on conceptual understanding and making connections, as well as the wider considerations of social, economic, global and environmental issues. Within the physics syllabus, it is stated that 'physics is a fundamental science which is concerned with the understanding of the natural world' and where such understanding is 'highly transferable to other disciplines, such as modelling of biological processes, weather patterns, earthquakes and even the movement of people or financial markets'. This links with the DP focus on conceptual understanding, as well as the use of knowledge, methods, tools and techniques that characterise science.

Within the SGA's learning outcomes, there is a notable lack of reference to technology. Whilst they do state that 'the fundamental theories of physics form the bedrock of many modern technologies', there is little explicit emphasis on developing the skills required for the use of technology.

Other Themes in the SGA

Although the vast majority of learning outcomes in the Singaporean curriculum feature similar themes to those found in the DP, the former places greater explicit emphasis on providing students with the necessary skills to continue studying the subject, or related subjects. This is explicitly mentioned in the first aim within H2 and H3, which highlights the intention for these syllabi to build the 'knowledge, skills and attitudes necessary for further studies in related fields'.[100] In this way, the Singaporean curriculum makes specific reference to future studies and to students having the ability to deepen their learning with further study, while the DP's learning outcomes, while also designed to prepare students for higher education, take a more implicit approach.

Summary

Like the DP, the Singaporean physics curriculum is heavily focused on conceptual learning and developing skills that allow for the use of science to solve problems at a global level. The outcomes are centred around the students being capable of linking multiple ideas, thinking critically to investigate issues and how science can impact and be affected by global issues. Whilst these themes are present in the SGA, the DP goes into further detail with regard to the importance of developing technological and collaboration skills, while the Singaporean learning outcomes place greater explicit emphasis on further study. Overall, however, the

[100] MOE, Singapore. (2021). *Physics syllabus. Pre-University Higher 2.* p.3

learning outcomes in the Singaporean physics curriculum are closely aligned with those of the DP, sharing predominantly similar themes and focuses.

5.2.2 Content – Physics

This section compares and contrasts the content of the DP and SGA curricula falling within the category of physics. In order to support visual comparison at-a-glance, the DP and SGA physics curricula are presented below in diagrams which show the key topics and sub-topics included in each.

Figure 15: DP physics content visualiser[101]

A. Space, time and motion	A.1 Kinematics	A.2 Forces and momentum	A.3 Work, energy and power	A.4 Rigid body mechanics (HL only)	A.5 Galilean and special relativity (HL only)
B. The particulate nature of matter	B.1 Thermal energy transfers	B.2 Greenhouse effect	B.3 Gas laws	B.4 Thermodynamics (HL only)	B.5 Current and circuits
C. Wave behaviour	C.1 Simple harmonic motion (SL + AHL)	C.2 Wave model	C.3 Wave phenomena (SL + AHL)	C.4 Standing waves and resonance	C.5 Doppler effect (SL + AHL)
D. Fields	D.1 Gravitational fields	D.2 Electric and magnetic fields	D.3 Motion in electromagnetic fields	D.4 Induction (HL only)	
E. Nuclear and quantum physics	E.1 Structure of the atom (SL + AHL)	E.2 Quantum physics (HL only)	E.3 Radioactive decay (SL + AHL)	E.4 Fission	E.5 Fusion and stars
Experimental programme	Practical work	Collaborative sciences project	Scientific investigation		

[101] '(HL only)' and '(SL + AHL)' are used to flag, respectively, topics only taught at HL and topics taught at both SL and HL, but which also feature additional higher level content.

Figure 16: SGA physics

All subjects	Core Ideas in Physics	1. Systems and interactions	2. Models and Representations	3. Conservation Laws			
H1 physics	I. Measurement	1. Measurement					
	II. Newtonian Mechanics	2. Kinematics	3. Dynamics	4. Forces	5. Work, Energy, Power	6. Motion in a Circle and Orbits	
	III. Electricity and Magnetism	7. Current of Electricity	8. D.C. Circuits	9. Electromagnetism			
	IV. Nuclear Physics	10. Nuclear Physics					
H2 physics	I. Measurement	1. Measurement					
	II. Newtonian Mechanics	2. Kinematics	3. Dynamics	4. Forces	5. Work, Energy, Power	6. Motion in a Circle and Orbits	7. Gravitational Field
	III. Thermal Physics	8. Temperature and Ideal Gases	9. First Law of Thermodynamics				
	IV. Oscillations and Waves	10. Oscillations	11. Wave Motion	12. Superstition			
	V. Electricity and Magnetism	13. Electric Fields	14. Current of Electricity	15. D.C. Circuits	16. Electromagnetism	17. Electromagnetism Induction	18. Alternating Current
	VI. Modern Physics	19. Quantum Physics	20. Nuclear Physics				
H3 physics	Newtonian Mechanics	A1. Inertial Frames (non-relativistic)	A2. Rotational Motion	A3. Planetary and Satellite Motion			
	Electricity and Magnetism	B1. Electric and Magnetic Fields	B2. Capacitors and Inductors				

Structure

DP physics is taught over two years, whereas the SGA curriculum is designed to be completed over two or three years, depending on the type of institution the student attends. Students choose to study H1 or H2 based on their ability, interest and potential future careers. H1 is 'designed to broaden students' learning that will support the development of scientific literacy'.[102] The H1 syllabus is focused on equipping students with the skills they need to make 'informed decisions based on sound scientific knowledge and principles'[103] so that they become citizens that can contribute positively to society. The H2 curriculum is intended to suit students who enjoy science and are capable of studying it at a deeper level than H1, laying 'a strong foundation of knowledge, skills and attitudes' in order to 'prepare students well for university, work and life in the future'.[104] For students who wish to extend their science skills and deepen their understanding, they may study H3 in addition to H2. The H3 syllabus is 'designed to build on and extend the knowledge, understanding and skills acquired from the H2 physics syllabus', catering to 'students of strong ability and keen interest in physics' and being 'designed with a strong emphasis on independent and self-directed learning'.[105] As such, the H3 syllabus goes into more depth than H1 and H2 and is intended to be a more challenging subject.

The DP organises its physics content into five over-arching themes with multiple sub-topics within these. Similarly, the H1 syllabus has four overarching themes with sub-topics within them. H2 consists of six overarching themes, each of which contains sub-topics; and the multiple H3 sub-topics are organised into two overarching themes. H3 contains the same sub-topics as H2 but deepens students' learning by the inclusion of extension topics within two of these. There are three extension topics within 'Newtonian mechanics' (A.1 Inertial frames, A.2 Rotational motion, and A.3 Planetary and satellite motion) and two extension topics within 'Electricity and magnetism' (B.1 Electric and magnetic fields and B.2 Capacitors and inductors). The SL and AHL content within the DP are clearly defined and separated, with entire sub-topics only studied if students are taking the subject at HL. Due to the design of the SGA, instead of offering one course with SL and AHL content, SGA offers three subjects which each have a separate syllabus. It is expected that students will cover all content of the subject(s) they choose to study. In addition, the DP outlines suggested teaching time to be allocated to both SL and HL content, while the H1, H2 and H3 curricula – or, in fact, all SGA curricula – do not contain this information. This may be due to the flexibility offered within the SGA, where students may spend either two or three years studying the qualification (depending on what type of institution they study in) and therefore the time devoted to each subject and topic may vary.

Content Alignment

To complement the analysis, the figure below represents a simplified summary of the SGA's content alignment, at topic-level, with DP physics (SL and AHL content). Following this figure is a table highlighting significant SGA content that is not in the DP.

[102] MOE, Singapore. (2020). *Physics syllabus. Pre-University Higher 1.* p.4.
[103] Ibid.
[104] MOE, Singapore. (2019). *Physics syllabus. Pre-University Higher 2.* p.1.
[105] MOE, Singapore. (2021). *Physics syllabus. Pre-University Higher 3.* p.3.

Figure 17: Summary of the content alignment the SGA physics H1, H2 and H3 has with the main topics of the DP physics

DP physics topics	SL presence in H1	AHL presence in H1	SL presence in H2	AHL presence in H2	SL presence in H3	AHL presence in H3
A Space, time and motion						
A.1 Kinematics		N/A		N/A		N/A
A.2 Forces and momentum		N/A		N/A		N/A
A.3 Work, energy and power		N/A		N/A		N/A
A.4 Rigid body mechanics	N/A		N/A		N/A	
A.5 Galilean and special relativity	N/A		N/A		N/A	
B The particulate nature of matter						
B.1 Thermal energy transfers		N/A		N/A		N/A
B.2 Greenhouse effect		N/A		N/A		N/A
B.3 Gas laws		N/A		N/A		N/A
B.4 Thermodynamics	N/A		N/A		N/A	
B.5 Current and circuits		N/A		N/A		N/A
C Wave behaviour						
C.1 Simple harmonic motion						
C.2 Wave model		N/A		N/A		N/A
C.3 Wave phenomena						
C.4 Standing waves and resonance		N/A		N/A		N/A
C.5 Doppler effect						
D Fields						
D.1 Gravitational fields						
D.2 Electric and magnetic fields						
D.3 Motion in electromagnetic fields		N/A		N/A		N/A
D.4 Induction	N/A		N/A		N/A	
E Nuclear and quantum physics						
E.1 Structure of the atom						
E.2 Quantum physics	N/A		N/A		N/A	
E.3 Radioactive decay						
E.4 Fission		N/A		N/A		N/A
E.5 Fusion and stars		N/A		N/A		N/A
Experimental programme						

* Where applicable, content alignments found in pre-requisite subjects are carried forwards and combined with new alignments to represent the cumulative content covered.

Key:

	Strong presence of this topic in the SGA.		*Partial presence of this topic in the SGA.*		*Little or no presence of this topic in the SGA.*	N/A	*This topic does not exist at the respective level.*

Table 20: SGA physics content which is not covered in the DP

Significant SGA content which is not included in DP physics*		
H1	H2	H3**
• FE and FB interactions • Thermistors • Biological effects of radiation	• FE and FB interactions • Thermistors • Biological effects of radiation • Upthrust • Alternating current • Polarisation • Balanced potentials and a potentiometer • Heisenberg position-momentum	• FE and FB interactions • Centre of mass frame • Gauss's law for electric and magnetic fields • Ampère's law for magnetic fields • Electric and magnetic dipoles • Capacitors and inductors

*Significant content will not focus on topics that are typically studied *prior* to upper secondary.
** Content listed in this column is specific to H3. As H2 is always studied alongside H3, all topics in the H2 column should be considered in addition to the topics in this column.

H1 physics

The H1 curriculum has some, albeit low, level of alignment with the DP SL content topics of A. Space, time and motion and D. Fields, and very limited alignment with topics B, C and E. Two sub-topics within topic A (A.1 Kinematics and A.2 Forces and momentum) show strong levels of alignment with H1, but only one sub-topic in B (B.5 Currents and circuits), D (D.1 Gravitational fields) and E (E.3 Radioactive decay) are aligned to the same degree. Sub-topics A.3 Work, energy and power, D.2 Electric and magnetic fields, and D.3 Motion in electromagnetic fields show some level of alignment. The breadth of content within A.3 Work, energy and power is very similar, as are the key concepts that make up this sub-topic. Some of the focus of SGA H1, such as to understand the principles of the conservation of energy, mechanical energy and power, reflect some of the core principles within the A. Space, time and momentum topic. The D.2 Electric and magnetic fields sub-topic of the DP has a similar coverage to that of the SGA in the core principles around conservation of electric charge and electric field lines. As to the DP sub-topic D.3 Motion in electromagnetic fields, the SGA shows partial alignment with the DP as it covers the core principles of this module but does not go beyond these. The motion of a charged particle, for example, is a fundamental part of the DP's D. Fields topic, but, beyond this, there is little alignment. When compared with the SL content of the DP, the breadth of the H1 physics curriculum is very narrow. There is no alignment with any AHL content within the H1 physics curriculum, meaning that alignment with DP physics HL is limited. This is, however, to be expected, as H2 and H3 are designed to cover content at both greater depth and breadth than H1.

H2 physics

The H2 curriculum has strong alignment with the SL content of the DP in terms of the breadth of topics covered. Within SL content, alignment can be observed with every main topic in the DP, with the highest level of alignment being with A. Space, time and motion and the lowest level of alignment being with topic E. Nuclear and quantum physics, where two sub-topics (E.4 Fission and E.5 Fusion and stars) are absent. As to the DP AHL content, there is good alignment with E. Nuclear physics and quantum physics, D. Fields for topics, and C. Wace behaviour. Significant AHL sub-topics that are particularly aligned are D.4 Induction, E.2 Quantum physics, and E.3 Radioactive decay. However, no AHL topics from A. Space, time and motion and B. The particulate nature of matter are present in SGA H2. Overall, H2 has

similar breadth to the DP physics curriculum, though at times differs slightly in the choice of concepts covered within a topic area. The inclusion of more advanced material, such as AHL topics from the DP, demonstrates that H2 surpasses SL in depth for some areas; however, there are fewer areas of depth than the HL overall.

H3 physics

As H2 must be offered with H3, then all previous alignments from H2 still apply. H3 extends some of the learning from H2, particularly in the areas of 'Newtonian mechanics' and 'Electric and magnetic fields'. Mostly, H3's coverage of these topics differs to DP AHL content, as different concepts, such as electric and magnetic dipoles, Gauss's Law, Ampere's law, and the use of calculus in the topic B.2 Capacitors and inductors (first and second order differential equations), are in H3 but not the DP. Though H3 does not significantly increase alignment with DP HL content, it can be noted that it gains a new alignment with the AHL sub-topic, A.4 Rigid body mechanics. As well as extended content, the focus of H3 is on solving challenging problems, analytical skills, appreciating the rigour of physics, and linking concepts and ideas from multiple areas of the curriculum. Overall, students taking H3 physics, in addition to H2, will be exposed to a similar breadth and depth of study as the DP HL, albeit with some differences in the content covered.

Summary

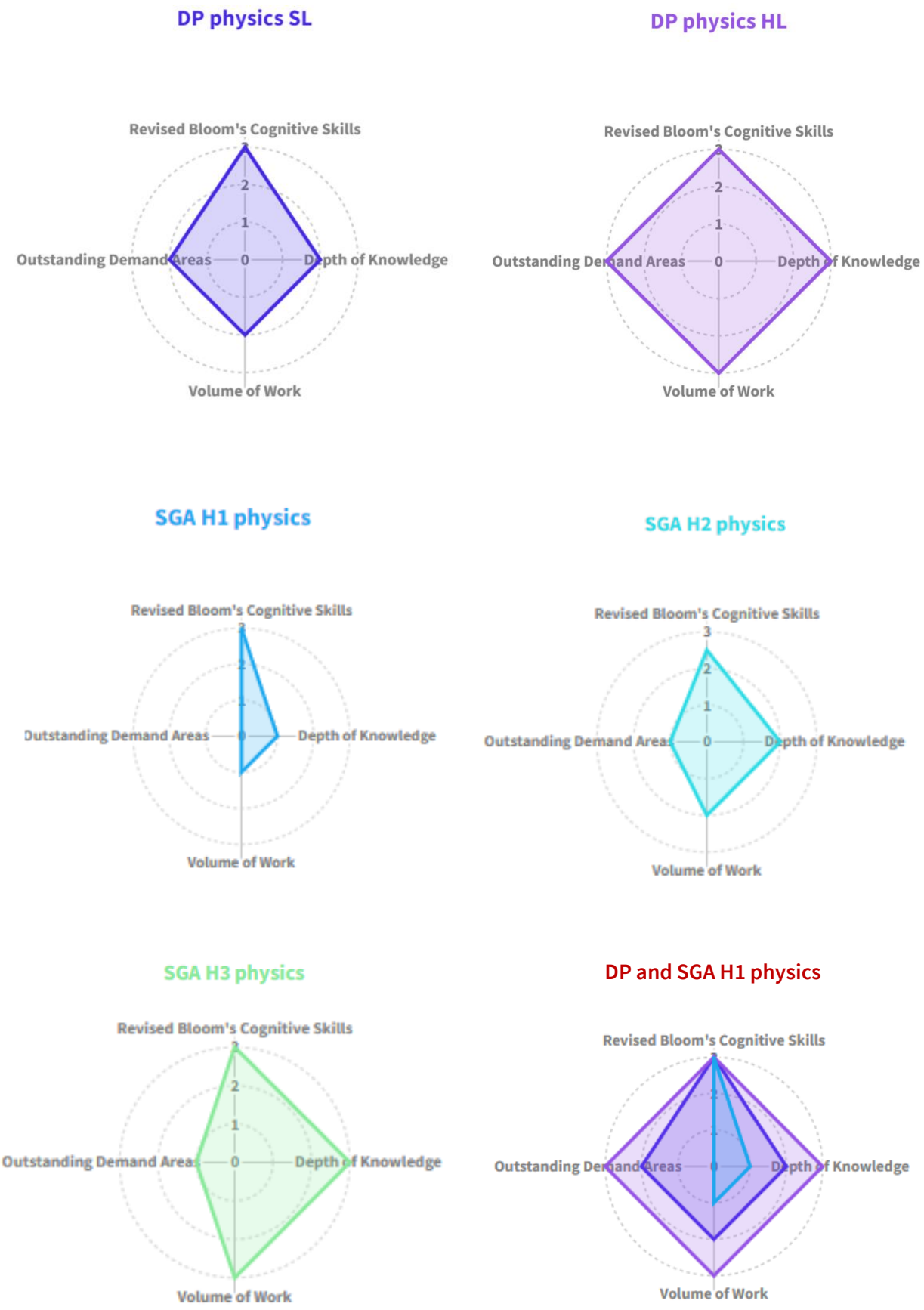
As the SGA curriculum progresses from H1 to H3, the alignment with the DP increases with the level – being lowest at H1 and highest at H3. Overall, H1 has only low-moderate alignment with DP, as it lacks the breadth and depth of both SL and HL. H2 has comparable breadth to the DP curriculum, and somewhat exceeds SL in the depth of certain topic areas. H3 demonstrates comparable breadth and depth to DP HL, despite differing in coverage of particular areas. Generally, most topics from the DP curriculum can be identified in the SGA, albeit with some slightly different coverage. That said, it can be noted that B.2 Greenhouse effect, C.5 Doppler effect, and E.4 Fission and E.5 Fusion and stars are not present in SGA physics. The experimental programme of the DP is highly aligned with all SGA curricula, within the section of the curriculum entitled 'demonstrating science inquiry skills'[106] it describes in detail how students are expected to plan and conduct investigations, obtain, analyse and evaluate their data and then communicate their findings. Although it is not explicit whether this is collaborative or independent work, the principles of the experimental programme are clearly within H1, H2 and H3 SGA physics.

5.2.3 Demand – Physics

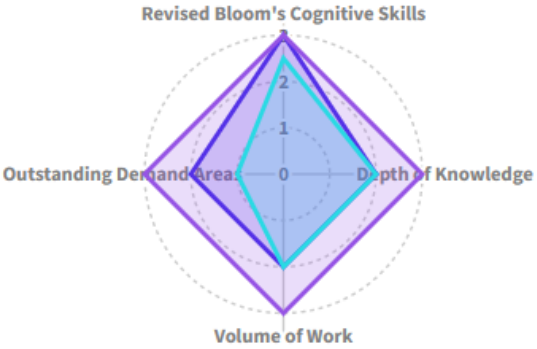
The DP and SGA curricula were analysed using the same demand tool in order to create a demand profile for DP physics SL, DP physics HL, SGA H1, SGA H2, and SGA H3. These demand profiles are presented below in the form of radar diagrams, with superimposed diagrams also being featured to enable immediate visual comparison.

[106]MOE, Singapore. (2020). *Physics syllabus. Pre-University Higher 1.* p.7; MOE, Singapore. (2019). *Physics syllabus. Pre-University Higher 2.* p.4; MOE, Singapore. (2021). *Physics syllabus. Pre-University Higher 3.* p.5

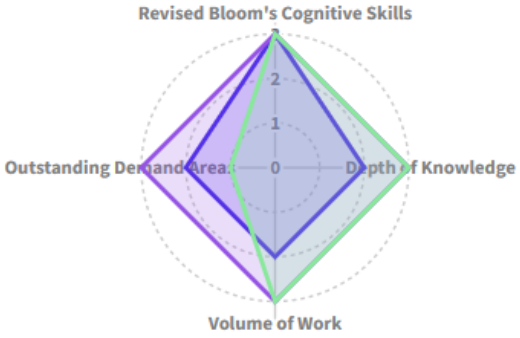
Figure 18: Visual representations of subject demand



DP and SGA H2 physics



DP and SGA H3 physics



The panel of experts carried out a detailed analysis of each course and reached a consensus on the scores shown in the profiles above. The following points were particularly important within the panel discussion:

- Regarding the scores for **Bloom's Cognitive Skills**:
  - DP physics has the same learning outcomes for both SL and HL, meaning that these scores are the same. These were judged to merit a score of 3 due to the high levels of critical thinking, critical awareness and elements of synthesis and creation present in the majority of aims and Assessment Objective 3.
  - A score of 2 was given to H1 physics as, while there is evidence of analysis and synthesis in the learning outcomes, the predominant focus of both outcomes and assessment objectives is on knowledge, understanding and applying. H2 physics was given a score of 2.5 as it features more higher order thinking, with some opportunities for analysis and synthesis, yet these were still not the predominant feature. For H3 physics, a score of 3 was awarded given the numerous references to higher order thinking skills, including problem solving and synthesis.

- Regarding the score for **Depth of Knowledge**:
  - DP physics SL was deemed to merit a score of 2 due to the mathematical pre-requisite skills and competences required to access the course, as well as the moderate to high level of cognitive complexity of the knowledge that students are expected to acquire. As to the HL course, the greater depth and additional opportunities provided for extended thinking in the additional higher level option topics pushed the score to a 3.
  - H1 physics was given a score of 1 due to the limited focus on investigation and the relatively basic nature of the content covered, which primarily requires mental processes such as 'identify', 'state', and 'recall'. For H2, a score of 2 was awarded to reflect the extended nature of the curriculum, where greater detail is observed. Finally, H3 physics, studied in addition to H2, covers topics in great detail and features multiple areas requiring extended thinking within and across topics, being awarded a score of 3.

- Regarding the scores for **Volume of Work**:
  - DP physics SL was judged to comprise a moderate-heavy workload (a score of 2) as students are exposed to multiple physics topics, with each topic being allocated a standard to short amount of time. The volume demands of the HL course, on the other hand, were found to be sufficient to meet a score of 3 as, even though the proportion of topics studied in the same amount of time is smaller, these topics are covered in great depth and with a focus on application.
  - H1 physics was awarded a score of 1 as the content is relatively simple and having one-two years of teaching time to cover it suggests that a lot of time can be spent on each topic. H2 curriculum is designed to take students' learning further. H2 is studied over a longer period of time – two-three years – but it features a higher number of challenging topics and skill development; hence the score of 2. H3 physics received a score of 3 as students must study it concurrently with H2; therefore, within the same two-three year timeframe, students are not only covering a higher number of topics, but also doing so at a greater depth, making the volume of work high.

- Regarding the scores for **Outstanding Areas of Subject Demand**:
  - For the DP physics SL course (awarded a score of 2), the IA scientific investigation research project that students need to undertake, the linking questions outlined in the syllabus and the collaborative sciences project were considered to be areas of stretch. In addition to the latter, the HL course features additional higher levels topics which were deemed to include additional areas of stretch, meriting a score of 3.
    - No stretch areas were found in the Singapore H1 physics; hence the score of 0. Within H2 physics, there are small topic areas, such as inductance, which could be considered as stretch, though these only make up a small part of the curriculum. However, when taken with the practical aspect emphasised in the course, this was deemed to amount to one area of stretch, resulting in a score of 1. The design of the H3 physics curriculum is intended to extend and deepen students' knowledge across multiple topics, therefore the areas of outstanding subject demand are not from specific topics, but from the ethos of the route of study. This was deemed to deserve a score of 1.

5.3 Chemistry

Below is the list of subjects used in the chemistry subject comparison analysis.

DP chemistry[107]
Chemistry is a subject option offered within the DP sciences subject group, at both SL and HL. This subject has content that is common to both SL and HL, as well as AHL content that is featured only in the HL. Thus, the HL has greater breadth and depth than SL. This subject is designed to prepare students for university courses such as medicine, biological science and environmental science. HL is suitable for those intending to pursue further study in an area requiring a strong background in chemistry.

SGA H1 chemistry[108]
H1 chemistry is designed to offer a science education that develops knowledge of core scientific ideas and an understanding of scientific inquiry. This will enable students to make decisions on science-related issues and challenges. H1 chemistry broadens students' learning and develops their scientific literacy by using real-world contexts, putting less emphasis on handling equipment and carrying out laboratory experiments, and instead focusing on developing scientific knowledge. The aim of the H1 syllabus is to enable students to become scientifically literate consumers who are able to make informed choices concerning science-related issues.

SGA H2 chemistry[109]
The H2 chemistry curriculum aims to prepare students well for university, work and life by laying a strong foundation of knowledge, skills and attitudes. Upon completing H2 chemistry, all students will be well-equipped to make informed decisions based on scientific knowledge, but H2 also caters for students who wish to pursue chemistry further. It gives students a deeper grasp of scientific knowledge and is designed to give students a more coherent and integrated understanding of science rather than a compartmentalised view of knowledge. Application is also a key component of the H2 chemistry curriculum; students are provided with real-world contexts in order to strengthen their understanding and deepen their scientific knowledge.

SGA H3 chemistry[110]
H3 chemistry is designed to build on and extend students' knowledge and understanding gained from H2 chemistry. Catering to students with a keen interest and strong ability in chemistry, there is a strong emphasis on independent and self-directed learning, and it aims to provide greater depth and rigour. H3 is designed for students who wish to pursue further studies in chemistry-related fields by providing them with a greater appreciation of the practice, value and rigour of chemistry, as well as deepening the knowledge, skills and attitudes gained through the study of H2.

[107] International Baccalaureate. (2023). *Chemistry guide*.
[108] MOE, Singapore. (2020). *Chemistry Syllabus. Pre-University Higher 1. Syllabus 8873.* Available from: pre-university-h1-chemistry-syllabus.ashx (moe.gov.sg)
[109] MOE, Singapore. (2019). *Chemistry Syllabus. Pre-University Higher 2. Syllabus 9729.* Available from: preuniversity_h2_chemistry_syllabus.ashx (moe.gov.sg)
[110] MOE, Singapore. (2021). *Chemistry Syllabus. Pre-University Higher 3. Syllabus 9813.* Available from: 2021-preu-h3-chemistry.ashx (moe.gov.sg)

5.3.1 Learning Outcomes – Chemistry

This section compares and contrasts the learning outcomes of curricula falling within the category of chemistry. The learning outcome themes for chemistry are structured in the same way as those for physics. See the physics overview in section 5.2.1 above for further detail.

The following table demonstrates the learning outcome themes that were extracted from the DP learning outcomes and indicates if and where they were judged to have presence within the learning outcomes of the SGA chemistry curricula.

Table 21: Presence of the DP sciences subject group learning outcome themes in the SGA chemistry curricula.

Themes extracted from the learning outcomes of the DP sciences subject group	Presence in the SGA	
1. Conceptual understanding and making connections		Present throughout PoS and aims. Students should connect between the sub-microscopic, macroscopic and symbolic levels, as well as build attitudes for further study in related fields.
2. Use and application of knowledge, methods, tools, and techniques that characterise science		Present throughout PoS and aims. Descriptions of science as evidence-based and model-building, as well as constructing explanations based on evidence support the presence of this theme.
3. Creativity and critical thinking (problem-solving, analysis, evaluation, synthesis)		Present throughout PoS and aims. SGA describes the analysis and interpretation of data, as well as using scientific principles to understand, analyse and evaluate systems.
4. Skills for scientific inquiry		Present. Found in PoS through statements concerning the planning and conducting of experimental procedures and obtaining and organising data appropriately.
5. Development of technological skills		Absent. Not found in PoS or H1, H2, or H3 aims.
6. Effective collaboration and communication		Partially present. Scientific communication is referenced in PoS in relation to communicating scientific knowledge and findings appropriately, but collaborative competence is not explicitly mentioned.
7. Awareness of global and local problems and the environmental, ethical, cultural, and social impact of science		Present throughout PoS and aims from the mention of scientific knowledge and problem-solving being influenced by economic, social, environmental and ethical factors.

Key:

	This theme is well-evidenced in the learning outcomes of the SGA.		*This theme is partially evidenced in the learning outcomes of the SGA.*		*This theme is not evident in the learning outcomes of the SGA.*

Presence of DP's Learning Outcome Themes

The DP's learning outcome themes one to four, six and seven are found to be present in the aims and PoS for chemistry H1, H2 and H3. Many statements throughout the PoS imply conceptual understanding and making connections: 'use appropriate models to explain concepts, solve problems and make predictions, 'make decisions based on evaluation of evidence, processes, claims and conclusions'. The aims of H1 and H2 also reflect this theme: 'connecting between the sub-microscopic, macroscopic and symbolic levels of representations'. Demonstrating, using and applying knowledge that characterises science is found throughout PoS and aims. PoS statements that refer to this include: 'understand that science is an evidence-based, model-building enterprise', 'use appropriate models to explain concepts, solve problems and make predictions', 'understand, analyse and evaluate real-world systems as well as generate solutions for problem solving'. Terminology within the aims include: 'understanding the nature of science enquiry skills', 'develop the way of thinking to explain phenomena, approach and solve problems in chemical systems'.

Creativity and critical thinking are also seen throughout the PoS and aims. 'Understand that the use of both logic and creativity is required in the generation of scientific knowledge' can be found in the PoS, as can 'make decisions based on evaluation of evidence, processes, claims and conclusions'. The aims within H3 are worded 'develop […] the skills to analyse chemical issues, and to apply relevant concepts and techniques to solve problems'.

The application of skills in order to carry out insightful and ethical investigations is covered in the PoS through 'identify scientific problems, observe phenomena and pose scientific questions/hypotheses', 'plan and conduct investigations' and 'obtain, organise and represent data in an appropriate manner'.

Communicating and collaborating effectively is only evident in two statements from the PoS: 'scientific knowledge is generated from consensus within the community of scientists through critical debate and peer review' and 'communicate findings and information using appropriate language and terminology'. Hence, whilst communication is present, collaboration is not explicitly mentioned in the SGA chemistry curricula.

The awareness of local and global problems and ethical, environmental, cultural and social impacts on science is referenced through the PoS, for example: 'science is […] connected with the natural world', 'recognise that […] problem-solving could be influenced by other considerations such as economic, social, environmental and ethical factors' and 'demonstrate an understanding of the benefits and risks associated with the application of science to society'. H1 and H2 aims discuss the importance of this theme through 'scientifically literate citizens who are well-prepared for the challenges of the 21st century […] relating science to society'.

The focus of H1, H2 and H3 aims is on conceptual understanding and making connections, as well as the wider considerations of social, economic, global and environmental issues. Within the chemistry syllabus, it is explained that 'chemistry is often seen to play a central role in science' and this expanded-upon by explaining how it is built on understanding of the laws of physics and provides a basis for studying reactions in biological systems. This links with the DP focus on conceptual understanding and making connections within, and across, subjects. Alongside this, there is a lot of similarity to the DP collaborative sciences project of addressing

real-world problems and integrating knowledge. Singapore has a strong focus on developing 21st Century Competencies (21CC) in students to enable outcomes of students becoming self-directed learners, confident people, concerned citizens and active contributors. These are overarching themes that should be embedded within science lessons and influence the learning outcomes.

Finally, within the SGA learning outcomes, there is no direct reference to technology, hence this DP theme of developing technological skills is not well-evidence in the SGA.

Other Themes in the SGA

Although the vast majority of learning outcomes in the Singaporean curriculum feature similar themes to those found in the DP, the former places greater explicit emphasis on providing students with the necessary skills to continue studying the subject, or related subjects. This is explicitly mentioned in the first aim within H2 and H3, which highlights the intention for these syllabi to build the 'knowledge, skills and attitudes necessary for further studies in related fields'.[111] In this way, the Singaporean curriculum makes specific reference to future studies and to students having the ability to deepen their learning with further study, while the DP's learning outcomes, while also designed to prepare students for higher education, take a more implicit approach.

Summary

Like the DP, the Singaporean chemistry curriculum is heavily focused on conceptual learning and developing skills that allow for the use of science to solve problems at a global level. The outcomes are centred around the students being capable of linking multiple ideas, thinking critically to investigate issues and how science can impact and be affected by global issues. Whilst these themes are present in the DP, the DP goes into further detail with regard to the importance of developing technological skills and working collaboratively, while the Singaporean curriculum seems to place greater emphasis on further study. Overall, however, the learning outcomes in the Singaporean chemistry curriculum are closely aligned with those of the DP, sharing predominantly similar themes and focuses.

5.3.2 Content – Chemistry

This section compares and contrasts the content of the DP and SGA curricula falling within the category of chemistry. In order to support visual comparison at-a-glance, the DP and SGA chemistry curricula are presented below in diagrams which show the key topics and sub-topics included in each.

[111] MOE, Singapore. (2019). *Chemistry syllabus. Pre-University Higher 2.* p.3

Figure 19: DP chemistry content visualiser[112]

Structure	**Structure 1. Models of the particulate nature of matter**	Structure 1.1 – Introduction to the particulate nature of matter	Structure 1.2 – The nuclear atom (SL + AHL)	Structure 1.3 – Electron Configurations (SL + AHL)	Structure 1.4 – Counting particles by mass: The mole	Structure 1.5 – Ideal gases
	Structure 2. Models of bonding and structure	Structure 2.1 – The ionic model	Structure 2.2 – The covalent model (SL + AHL)	Structure 2.3 – The metallic model (SL + AHL)	Structure 2.4 – From models to materials (SL + AHL)	
	Structure 3. Classification of matter	Structure 3.1 – The periodic table: Classification of elements (SL + AHL)	Structure 3.2 – Functional groups: Classification of organic Compounds (SL + AHL)			
Reactivity	**Reactivity 1. What drives chemical reactions?**	Reactivity 1.1 – Measuring enthalpy changes	Reactivity 1.2 – Energy cycles in reactions (SL + AHL)	Reactivity 1.3 – Energy from fuels	Reactivity 1.4 – Entropy and spontaneity (HL only)	
	Reactivity 2. How much, how fast and how far?	Reactivity 2.1 – How much? The amount of chemical change	Reactivity 2.2 – How fast? The rate of chemical change (SL + AHL)	Reactivity 2.3 – How far? The extent of chemical change (SL + AHL)		
	Reactivity 3. What are the mechanisms of chemical change?	Reactivity 3.1 – Proton transfer reactions (includes AHL)	Reactivity 3.2 – Electron transfer reactions (SL + AHL)	Reactivity 3.3 – Electron sharing reactions	Reactivity 3.4 – Electron-pair sharing reactions (SL + AHL)	
Experimental programme	Practical work	Collaborative sciences project	Scientific investigation			

[112] '(HL only)' and '(SL + AHL)' are used to flag, respectively, topics only taught at HL and topics taught at both SL and HL, but which also feature additional higher level content.

Figure 20: SGA chemistry content visualiser

H1 chemistry	**Core Idea 1: Matter**	1 Atomic Structure	2 Chemical Bonding			
	Core Idea 2: Structure and Properties	2 Chemical Bonding	3 Theories of Acids and Bases	4 Periodic Table		
	Core Idea 3: Transformation	5 The Mole Concept and Stoichiometry	6 Chemical Energetics: Thermochemistry	7 Reaction Kinetics	8. Chemical Equilibria	
	Extension Topic	9 Materials				
H2 chemistry	**Core Idea 1: Matter**	1 Atomic Structure				
	Core Idea 2: Structure and Properties	2 Chemical Bonding	3 The Gaseous State	4 Theories of Acids and Bases	5 The Periodic Table	
	Core Idea 3: Transformation	6 The Mole Concept and Stoichiometry	7 Chemical Energetics: Thermochemistry and Thermodynamics (Gibbs Free Energy and Entropy)	8 Reaction Kinetics	9 Chemical Equilibria	
	Extension Topics	10 Chemistry of Aqueous Solutions 10.1 Acid-Base Equilibria 10.2 Solubility Equilibria	11. Organic Chemistry 11.1 Introduction 11.2 Isomerism			
H3 chemistry	**Additional Content 1: Spectroscopic Techniques**	1.1 Basic Principles of Spectroscopy	1.2 Ultraviolet/visible Spectroscopy	1.3 Infra-red (IR) Spectroscopy	1.4 Nuclear Magnetic Resonance (NMR) Spectroscopy	1.5 Mass Spectroscopy
	Additional Content 2: Further Organic Matter	2.1 Molecular Stereochemistry	2.2 Basic Physical Organic Chemistry	2.3 Nucleophilic Substitution	2.4 Elimination	

Structure

DP chemistry is taught over two years, whereas the Singaporean curriculum is designed to be completed over two or three years, depending on the type of institution the student attends. Students choose to study H1 or H2 depending on their ability, interest and potential future careers. H1 is 'designed to broaden students' learning that will support the development of scientific literacy'. The H1 syllabus is focused on equipping students with the skills they need to make 'informed decisions based on sound scientific knowledge and principles' so that they become citizens that can contribute positively to society. The H2 curriculum is intended to suit students who enjoy science and are capable of studying it at a deeper level than H1, laying 'a strong foundation of knowledge, skills and attitudes' in order to 'prepare students well for university, work and life in the future'.[113] For students who wish to extend their science skills and deepen their understanding, they may study H3 in addition to H2. The H3 is syllabus is 'designed to build on and extend the knowledge, understanding and skills' acquired from the H2 chemistry syllabus', catering to 'students of strong ability and keen interest in chemistry', and being 'designed with a strong emphasis on independent and self-directed learning'.[114] As such, the H3 syllabus goes into more depth than H1 and H2 and is intended to be a more challenging subject.

The DP organises chemistry content into two over-arching themes of 'Structure' and 'Reactivity', with each theme containing three main topics. The curriculum is further sub-divided into smaller topics within these three sections. Somewhat similarly, the H1 and H2 syllabi each have three overarching themes, referred to as 'Core Ideas', which are 'Matter', 'Structure and Properties', and 'Transformation', as well as 'Extension Topics'. The SL and HL content within the DP are clearly defined and separated, with entire sub-topics only studied if students are studying HL. Due to the design of the SGA, instead of offering one course with SL and AHL content, SGA offers three subjects which each have a separate syllabus. It is expected that students will cover all content of whichever subject(s) they choose to study. Moreover, the DP outlines suggested teaching time to be allocated to both SL and HL content, while all SGA curricula do not contain this information. This may be due to the flexibility within the SGA, where students may spend either two or three years studying this course (depending on what type of institution they study in) and therefore the time devoted to each topic may vary.

While, in terms of overarching topics, the DP is subdivided into 'Reactivity' and 'Structure', each with multiple topics within, H3 is divided into 'Spectroscopic Techniques' and 'Further Organic Mechanisms', each of which also consists of multiple sub-topics. Due to the design of the SGA, all H3 content is compulsory, and students offering H3 must offer H2, meaning that all H2 content is also covered. There are no distinct 'extension topics' within the H3 syllabus; rather, the subject is designed in such a way that certain topics covered in H2 are extended into different contexts. For example, 'the concepts of chemical bonding and the periodic table is extended to the […] transition metals'.[115] Although the SGA H3 chemistry structure appears somewhat more simplistic than the DP, it has a stronger focus on applications, allowing students to 'apply relevant concepts and skills from H2 to tackle a more

[113] MOE, Singapore. (2019). *Chemistry syllabus. Pre-University Higher 2.* p.1.
[114] MOE, Singapore. (2021). *Chemistry syllabus. Pre-University Higher 3.* p.3
[115] Ibid. p.7.

diverse range of problems'.[116] Higher level thinking skills are encouraged through analysis, synthesis and application of knowledge in order to broaden students' ability in chemistry.

Content Alignment

To complement the analysis, the figure below represents a simplified summary of the SGA's content alignment, at topic-level, with DP chemistry (SL and AHL content). Following this figure is a table highlighting significant SGA content that is not in the DP.

Figure 21: Summary of the content alignment the SGA chemistry H1, H2 and H3 has with the main topics of the DP chemistry

DP chemistry topics	SL presence in H1	AHL presence in H1	SL presence in H2	AHL presence in H2	SL presence in H3	AHL presence in H3
Structure 1 Models of the particulate nature of matter						
1.1 Introduction to the particulate nature of matter		N/A		N/A		N/A
1.2 The nuclear atom						
1.3 Electron configurations						
1.4 Counting particles by mass: The mole		N/A		N/A		N/A
1.5 Ideal gases		N/A		N/A		N/A
Structure 2 Models of bonding and structure						
2.1 The ionic model		N/A		N/A		N/A
2.2 The covalent model						
2.3 The metallic model						
2.4 From models to materials						
Structure 3 Classification of matter						
3.1 The periodic table: Classification of elements						
3.2 Functional groups: Classification of organic compounds						
Reactivity 1 What drives chemical change?						
1.1 Measuring enthalpy changes		N/A		N/A		N/A
1.2 Energy cycles in reactions						
1.3 Energy from fuels		N/A		N/A		N/A
1.4 Entropy and spontaneity	N/A		N/A		N/A	
Reactivity 2 How much, how far and how fast?						
2.1 How much? The amount of chemical change		N/A		N/A		N/A
2.2 How fast? The rate of chemical change						
2.3 How far? The extent of chemical change						
Reactivity 3 What are the mechanisms of chemical change?						
3.1 Proton transfer reactions						
3.2 Electron transfer reactions						
3.3 Electron sharing reactions		N/A		N/A		N/A
3.4 Electron-pair reactions						
Experimental programme						

* Where applicable, content alignments found in pre-requisite subjects are carried forwards and combined with new alignments to represent the cumulative content covered.

[116] Ibid. p.8.

Key:

	Strong presence of this topic in the SGA.		*Partial presence of this topic in the SGA.*		*Little or no presence of this topic in the SGA.*	N/A	*This topic does not exist at the respective level.*

Table 22: SGA chemistry content which is not covered in the DP

Significant SGA content which is not included in DP chemistry*		
H1	**H2**	**H3****
• Nanomaterials • Trends and variations of oxides and chlorides • Half-life and first order reactions • Elimination	• Trends and variations of oxides and chlorides • Half-life and first order reactions • Homogeneous and heterogeneous catalysis • Solubility equilibria • The Faraday constant • Elimination	• Molecular stereochemistry • Elimination

*Significant content mostly does not include topics that are typically studied *prior* to upper secondary
**Content listed in this column is specific to H3. As H2 is always studied alongside H3, all topics in the H2 column should be considered in addition to the topics in this column

H1 chemistry

At both SL and HL, the H1 chemistry curriculum has strong alignment with the DP in terms of the number of topics covered and, to a lesser extent, the depth of these topics. There are very few DP topics and sub-topics that are completely absent from H1, making the breadth of the H1 curriculum very similar to that of the DP. At SL, only two areas of the DP's Reactivity 3 topics (3.2 – Electron transfer reactions and 3.3 – Electron sharing reactions) are not present in H1 chemistry, and while Structure 1.5 – Ideal gases and Reactivity 1.3 – Energy from fuels are also absent, all other areas of the DP were found to have some alignment with the H1, even if only partial.

When comparing the AHL content of the DP with H1 chemistry, however, there are evident gaps in topic coverage. There are many partial alignments across the AHL content and H1; for example, Structure 1.3 – Electron configurations and Structure 2.2 – The covalent model. As well as Reactivity 3.1 – Proton transfer reactions, which is the only sub-topic within Reactivity 3 to have any alignment to the DP AHL content. This is to be expected, as H1 aims to provide a firm foundation of chemistry understanding, with H2 and H3 designed to cover content at greater depth than H1.

H2 chemistry

As seen in the content alignment summary figure above, the topic coverage in the H2 curriculum has strong alignment with the content of the DP at both SL and HL. There is only one area at SL (Structure 2.4 – From models to materials) where no alignment was found. Most other areas were found to have strong alignment, reflecting a similarity of breadth between the H2 chemistry syllabus and the DP.

Most of the DP AHL content is also covered in H2, although, interestingly, the AHL content of Structure 2.2 – The covalent model – is absent from H2, despite being partially covered in H1. In addition to this, only one other DP area is entirely not present in H2 chemistry, Structure

3.2 – Electron transfer reactions. Overall, the content of the H2 chemistry curriculum shows relatively strong alignment with the DP HL.

H3 chemistry

There is strong alignment between H3 chemistry and both the SL and AHL aspects of the DP curriculum. The breadth of the H3 curriculum is highly aligned to the DP, with only one subtopic (Structure 2.4 – From models to materials) showing little or no alignment. All other areas show partial or high levels of alignment. The depth of the H3 syllabus is highly aligned to the DP AHL content, with all areas aligned to either a partial or high extent. Both the breadth and depth of the H3 syllabus is more aligned to the DP than H1 and H2.

Summary

Overall, the SGA chemistry curricula, as a whole, is strongly aligned with the DP chemistry syllabus, as both their breadth and depth of content are similar. There are some areas where content does not align – for instance, within the Structure section, SL content from 2.4 – From models to materials, and AHL content from 3.2 – Functional groups. However, taking into account the number of shared content areas and depth of coverage in those areas, the level of content alignment between all H1, H2 and H3 chemistry courses and the DP is high. The experimental programme of the DP is highly aligned with all SGA curricula, within the section of the curriculum entitled 'demonstrating science inquiry skills'[117] it describes in detail how students are expected to plan and conduct investigations, obtain, analyse and evaluate their data and then communicate their findings. Although it is not explicit whether this is collaborative or independent work, the principles of the experimental programme are clearly within H1, H2 and H3 SGA chemistry.

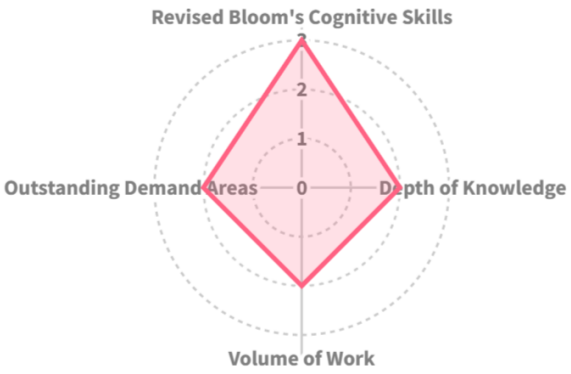
5.3.3 Demand – Chemistry

The DP and SGA curricula were analysed using the same demand tool in order to create a demand profile for DP chemistry SL, DP chemistry HL, SGA H1 chemistry, H2, and H3. These demand profiles are presented below in the form of radar diagrams, with superimposed diagrams also being featured to enable immediate visual comparison.

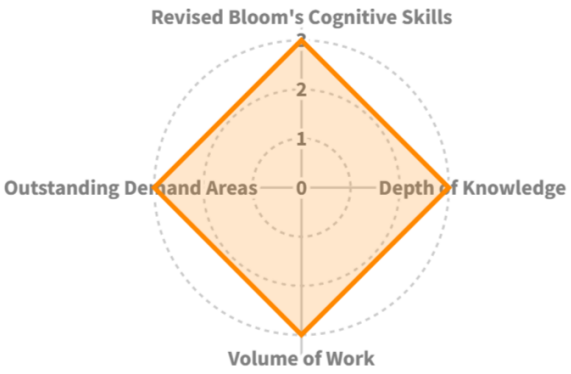
[117] MOE, Singapore (2020). *Chemistry syllabus. Pre-University Higher 1.* p.4; MOE, Singapore (2019). *Chemistry syllabus. Pre-University Higher 2.* p.5; MOE, Singapore (2021). *Chemistry syllabus. Pre-University Higher 3.* p.5

Figure 22: Visual representations of subject demand

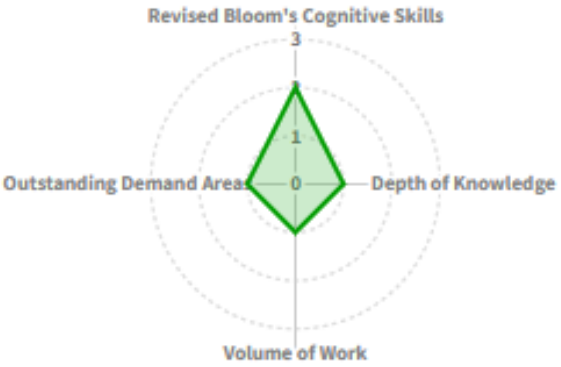
DP chemistry SL



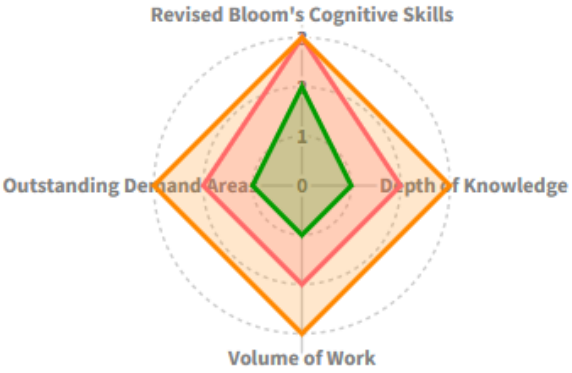
DP chemistry HL



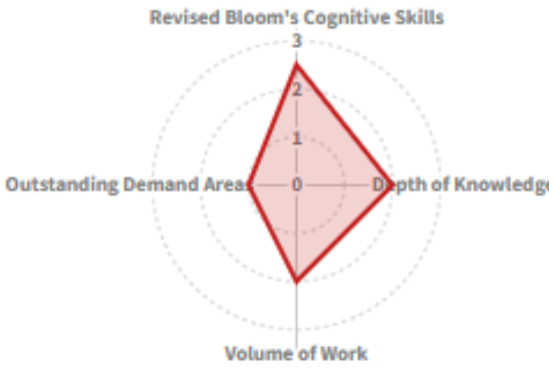
SGA H1 chemistry



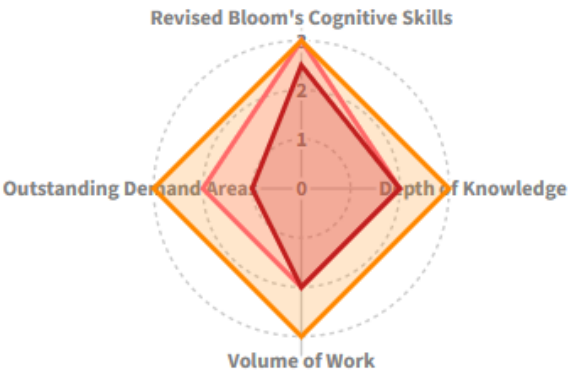
DP and SGA H1 chemistry

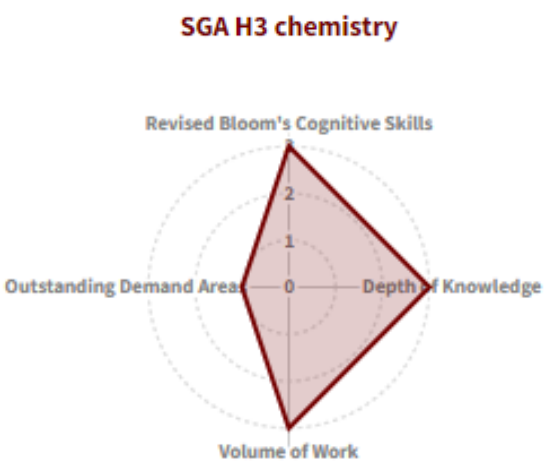


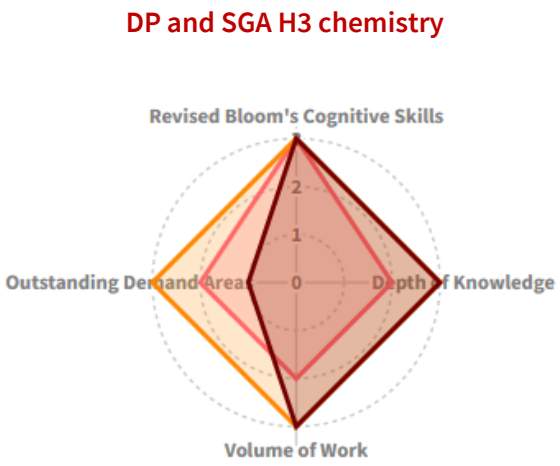
SGA H2 chemistry



DP and SGA H2 chemistry







- Regarding the scores for **Bloom's Cognitive Skills**:
  - DP chemistry has the same learning outcomes for both SL and HL, meaning that these scores are the same. These were judged to merit a score of 3 due to the high levels of critical thinking, critical awareness and elements of synthesis and creation present in the majority of aims and Assessment Objective 3.
  - A score of 2 was given to H1 chemistry as, while there is some evidence of analysis and synthesis in the learning outcomes, the predominant focus of both outcomes and assessment objectives is on knowledge and understanding and applying and evaluating. H2 chemistry was given a score of 2.5 as it features more higher order thinking, with some opportunities for analysis and synthesis, yet these were still not the predominant feature. For H3 chemistry, a score of 3 was awarded given the numerous references to higher order thinking skills, including problem solving and synthesis.

- Regarding the score for **Depth of Knowledge**:
  - DP chemistry SL was deemed to merit a score of 2 for depth of knowledge due to the mathematical pre-requisite skills and competences required to access the course, as well as the moderate to high level of cognitive complexity of the knowledge that students are expected to acquire. As to the HL course, the greater depth and additional opportunities provided for extended thinking in the additional higher level option topics pushed the score to a 3.
  - H1 chemistry was given a score of 1 due to the majority of content being focused on foundational concepts and requiring lower-level thinking skills, such as 'identify, state, define and outline'. For H2, a score of 2 was awarded to reflect the extended nature of the curriculum, where greater detail is observed. Finally, H3 chemistry, studied in addition to H2, covers topics in great detail and features multiple areas requiring extended thinking within and across topics, being awarded a score of 3.

- Regarding the scores for **Volume of Work**:
  - DP chemistry SL was judged to comprise a moderate-heavy workload (a score of 2) as students are exposed to various chemistry topics, with each topic being allocated a standard to short amount of time. The volume demands of the HL course, on the other hand, were found to be sufficient to meet a score of 3 – even

though the number of topics per hour is smaller, these topics are covered in great depth and with a focus on application.
    - H1 chemistry was awarded a score of 1 as the content is relatively simple and having two-three years of teaching time to cover it suggests that a lot of time can be spent on each topic. H2 curriculum provides more challenge for students as it is designed to take students' learning further. H2 is studied over a longer period of time – two-three years – but it features a higher number of challenging topics and skill development; hence the score of 2. H3 chemistry received a score of 3 as students must study it concurrently with H2; therefore, within the same two-three year timeframe, students are not only covering a higher number of topics, but also doing so at a greater depth, making the volume of work high.

- Regarding the scores for **Outstanding Areas of Subject Demand**:
    - For the DP chemistry SL course (awarded a score of 2), the IA scientific investigation research project that students need to undertake, the linking questions outlined in the syllabus and the collaborative science project were seen to be areas of stretch. In addition to the latter, the HL course features additional higher level topics which were deemed to include additional areas of stretch, meriting a score of 3.
    - When taking multiple aspects into account, H1 chemistry was given a score of 1. This was reached based on the extension topics 9.1 Nanomaterials and 9.2 Polymers, which feature some elements of advanced content and potential for students to explore and extend their understanding. For H2 chemistry, a score of 1 was given due to the inclusion of the K_{sp} topic as well as the references to real-life applications of knowledge. As with physics, the design of the H3 chemistry curriculum is intended to extend and deepen students' knowledge across multiple topics, therefore the areas of outstanding subject demand are not from specific topics, but from the ethos of the route of study. This was deemed to deserve a score of 1.

5.4 Biology

Below is the list of subjects used in the biology subject comparison analysis.

DP biology[118]
Biology is a subject option within the DP sciences subject group, offered at both SL and HL. This subject has content that is common to both SL and HL, as well as AHL content for HL. Thus, HL has greater breadth and depth than SL. This subject is designed to prepare students for university courses such as biology, medicine, dentistry, and biomedical engineering. HL is suitable for those intending to pursue further study in an area requiring a strong background in biology.

SGA H1 biology[119]
H1 biology is designed to offer a science education that develops knowledge of core scientific ideas and an understanding of scientific inquiry. This will enable students to make decisions on science-related issues and challenges. H1 biology broadens students' learning and develops their scientific literacy by using real-world contexts; putting less emphasis on handling equipment and carrying out laboratory experiments, and instead focusing on developing scientific knowledge. The aim of the H1 syllabus is to enable students to become scientifically literate consumers who are able to make informed choices concerning science-related issues.

SGA H2 biology[120]
The H2 biology curriculum aims to prepare students well for university, work and life by laying a strong foundation of knowledge, skills and attitudes. Upon completing H2 biology, all students will be well-equipped to make informed decisions based on scientific knowledge, but H2 also caters for students who wish to pursue biology further. It gives students a deeper grasp of scientific knowledge and is designed to give students a more coherent and integrated understanding of science rather than a compartmentalised view of knowledge. Application is also a key component of the H2 biology curriculum; students are provided with real-world contexts in order to strengthen their understanding and deepen their scientific knowledge.

SGA H3 biology[121]
H3 biology is designed to build on and extend students' knowledge and understanding gained from H2 biology. Catering to students with a keen interest and strong ability in biology, there is a strong emphasis on independent and self-directed learning, and it aims to provide greater depth and rigour. H3 is designed for students who wish to pursue further studies in biology-related fields by providing them with a greater appreciation of the practice, value and rigour of biology, as well as deepening the knowledge, skills and attitudes gained through the study of H2.

[118] International Baccalaureate. (2023). *Biology guide*.
[119] MOE, Singapore. (2020). *Biology Syllabus. Pre-University Higher 1. Syllabus 8876.* Available from: pre-university-h1-biology.ashx (moe.gov.sg)
[120] MOE, Singapore. (2019). *Biology Syllabus. Pre-University Higher 2. Syllabus 9744.* Available from: pre university_h2_biology_syllabus.ashx (moe.gov.sg)
[121] MOE, Singapore. (2021). *Biology Syllabus. Pre-University Higher 3. Syllabus 9816.* Available from: 2021-preu-h3-biology.ashx (moe.gov.sg)

5.4.1 Learning Outcomes – Biology

This section compares and contrasts the learning outcomes of curricula falling within the category of biology. The learning outcome themes for biology are structured in the same way as those for physics and chemistry. See the physics overview in section 5.2.1 above for further detail.

The following table demonstrates the learning outcome themes that were extracted from the DP learning outcomes and indicates if and where they were judged to have presence within the learning outcomes of the SGA biology curricula.

Table 23: Presence of the DP sciences subject group learning outcome themes in the SGA biology curricula

Themes extracted from the learning outcomes of the DP sciences subject group	Presence in the SGA	
1. Conceptual understanding and making connections		Present throughout PoS and aims where students assess the broader questions of what life is and how micro-systems interact at the physiological and organismal levels.
2. Use and application of knowledge, methods, tools, and techniques that characterise science		Present throughout PoS and aims through the development of an appreciation of the practice, value and rigour of biology as a discipline.
3. Creativity and critical thinking (problem-solving, analysis, evaluation, synthesis)		Present throughout PoS and aims. The SGA describes how logic and creativity are required to generate scientific knowledge as well as observing phenomena and posing scientific questions/hypotheses.
4. Skills for scientific inquiry		Present. Found in PoS where students must plan and conduct investigations by selecting appropriate procedures and apparatus, as well as obtaining and organising data.
5. Development of technological skills		Absent. Not found in PoS or H1, H2, or H3 aims.
6. Effective collaboration and communication		Partially present. Scientific communication is referenced in PoS in relation to communicating scientific knowledge and findings appropriately, but collaborative competence is not explicitly mentioned.
7. Awareness of global and local problems and the environmental, ethical, cultural, and social impact of science		Present throughout PoS and aims from the emphasis on scientific problem-solving being influenced by economic, social and environmental factors.

Key:

	This theme is well-evidenced in the learning outcomes of the SGA.		*This theme is partially evidenced in the learning outcomes of the SGA.*		*This theme is not evident in the learning outcomes of the SGA.*

Presence of DP's Learning Outcome Themes

The DP's learning outcome themes one to four, six and seven are found to be present in the aims and PoS for biology H1, H2 and H3. Many statements throughout the PoS imply conceptual understanding and making connections: 'use appropriate models to explain concepts, solve problems and make predictions', 'make decisions based on evaluation of evidence, processes, claims and conclusions'. The aims of H1 and H2 also reflect the theme 'address the broader questions of what life is […] making connections to how systems interact'; with more intricate reference to it in H3 aims 'writing well-structured arguments that integrate knowledge and skills acquired from different areas of biology'. Demonstrating, using and applying knowledge that characterises science is found throughout the PoS and aims. PoS statements that refer to this include: 'understand that science is an evidence-based, model-building enterprise', 'use appropriate models to explain concepts, solve problems and make predictions', 'understand, analyse and evaluate real-world systems as well as to generate solutions for problem solving'. Terminology within the aims include 'demonstrating science inquiry skills', 'develop in students an appreciation of the practice, value and rigour of biology as a discipline'.

The PoS and aims demonstrate critical thinking skills through their expectations that students plan and conduct insightful and ethical investigations and obtain, organise and represent data. The reference within the aims of scientific knowledge being 'subject to revision in the light of new evidence' links well with this theme, as well as 'make decisions based on evaluation of evidence, processes, claims and conclusions'. H1, H2 and H3 all have the same aim relating to this theme which includes 'demonstrating science enquiry skills'.

The application of skills in order to carry out insightful and ethical investigations is covered in the PoS through statements such as 'identify scientific problems, observe phenomena and pose scientific questions/hypotheses', 'plan and conduct investigations' and 'obtain, organise and represent data in an appropriate manner'.

The awareness of local and global problems and ethical, environmental, cultural and social impacts on science is well referenced and strongly present throughout all SGA aims. PoS statements include 'model-building enterprise concerned with the natural world' and 'scientific knowledge to problem solving could be influenced by […] economical, social, environmental and ethical factors'. The PoS also make reference to applying scientific principles and understanding the analysis and evaluation of 'real-world systems' in order to 'generate solutions for problem solving'. The aims of H1 and H2 explicitly state the importance of enabling students to become 'scientifically literate citizens who are well-prepared for the challenges of the 21st century' as well as being confident in 'relating science to society'. The fourth aim for H1 and H2 covers this theme well by stating that students will 'address the broader questions of what life is and[be having] an interest in and demonstrating a care for the local and global environment'.

In SGA biology, there is reference to communication, though not collaboration in the PoS. However, the H3 biology syllabus aims demonstrates this DP theme more strongly than H1 and H2 by including the statements 'respond through well-structured arguments' and 'develop […] the skills needed for effective communication to different audiences'.

The focus of H1, H2 and H3 aims is based around conceptual understanding and making connections, as well as the wider considerations of social, economic, global and environmental issues. This links with the DP's collaborative sciences project of addressing real-world problems and integrating knowledge. The SGA has a strong focus on developing 21st Century Competencies (21CC) within students, to enable them to become self-directed learners, confident people, concerned citizens and active contributors. These are overarching themes that should be embedded within science lessons and influence the learning outcomes.

Within the SGA biology learning outcomes, there is no explicit reference to developing skills for the use of technology, hence this DP theme is not well-evidenced in the SGA learning outcomes.

Other Themes in the SGA

Although the vast majority of learning outcomes in the Singaporean curriculum feature similar themes to those found in the DP, the former places greater explicit emphasis on providing students with the necessary skills to continue studying the subject, or related subjects. This is explicitly mentioned in the first aim within H2 and H3, which highlights the intention for these syllabi to build the 'knowledge, skills and attitudes necessary for further studies in related fields'. In this way, the Singaporean curriculum makes specific reference to future studies and to students having the ability to deepen their learning with further study, while the DP's learning outcomes, while also designed to prepare students for higher education, take a more implicit approach.

Summary

Like the DP, the Singaporean biology curriculum is heavily focused on conceptual learning and developing skills that allow for the use of science to solve problems at a global level. The outcomes are centred around the students being capable of linking multiple ideas, thinking critically to investigate issues and how science can impact and be affected by global issues. Whilst these themes are present in the DP, the DP goes into further detail with regard to the importance of developing technological and collaboration skills, while the Singaporean curriculum seems to place greater emphasis on further study. Overall, however, the learning outcomes in the Singaporean biology curriculum are closely aligned with those of the DP, sharing predominantly similar themes and focuses.

5.4.2 Content – Biology

This section compares and contrasts the content of the DP and SGA curricula falling within the category of biology. In order to support visual comparison at-a-glance, the DP and SGA biology curricula are presented below in diagrams which show the key topics and sub-topics included in each.

Figure 23: DP biology content visualiser[122]

A: Unity and diversity	**1. Molecules**	A1.1 Water (SL + AHL)	A1.2 Nucleic acids (SL + AHL)	
	2. Cells	A2.1 Origins of cells (HL only)	A2.2 Cell structure (SL + AHL)	A2.3 Viruses (HL only)
	3. Organisms	A3.1 Diversity of Organisms (SL + AHL)	A3.2 Classification and cladistics (HL only)	
	4. Ecosystems	A4.1 Evolution and speciation (SL + AHL)	A4.2 Conservation and biodiversity	
B: Form and function	**1. Molecules**	B1.1 Carbohydrates and lipids	B1.2 Proteins (SL + AHL)	
	2. Cells	B2.1 Membranes and membrane transport (SL + AHL)	B2.2 Organelles and compartmentalization (SL + AHL)	B2.3 Cell specialization (SL + AHL)
	3. Organisms	B3.1 Gas exchange (SL + AHL)	B3.2 Transport (SL + AHL)	B3.3 Muscle and mobility (HL only)
	4. Ecosystems	B4.1 Adaptation to environment	B4.2 Ecological niches	
C: Interaction and independence	**1. Molecules**	C1.1 Enzymes and metabolism (SL + AHL)	C1.2 Cell respiration (SL + AHL)	C1.3 Photosynthesis (SL + AHL)
	2. Cells	C2.1 Chemical signalling (HL only)	C2.2 Neural signalling (SL + AHL)	
	3. Organisms	C3.1 Integration of body systems (SL + AHL)	C3.2 Defence against disease	
	4. Ecosystems	C4.1 Populations and communities	C4.2 Transfers of energy and matter	
D: Continuity and change	**1. Molecules**	D1.1 DNA replication (SL + AHL)	D1.2 Protein synthesis (SL + AHL)	D1.3 Mutations and gene editing (SL + AHL)
	2. Cells	D2.1 Cell and nuclear division (SL + AHL)	D2.2 Gene expression (HL only)	D2.3 Water potential (SL + AHL)
	3. Organisms	D3.1 Reproduction (SL + AHL)	D3.2 Inheritance (SL + AHL)	D3.3 Homeostasis (SL + AHL)
	4. Ecosystems	D4.1 Natural selection (SL + AHL)	D4.2 Sustainability and change (SL + AHL)	D4.3 Climate change (SL + AHL)
Experimental programme	Practical work	Collaborative sciences project	Scientific investigation	

[122] '(HL only)' and '(SL + AHL)' are used to flag, respectively, topics only taught at HL and topics taught at both SL and HL, but which also feature additional higher level content.

Figure 24: SGA biology content visualiser

H1 biology	Core Idea 1: The Cell and Biomolecules of Life	A. Organelles and Cellular Structures	B. Biomolecules of Life and Cellular Transport	C. Proteins	D. Stem Cells		
	Core Idea 2: Genetics and Inheritance	A. The Structure of Nucleic Acids and Gene Expression	B. DNA Mutations	C. The Cell Cycle	D. Inheritance		
	Core Idea 3: Energy and Equilibrium						
	Core Idea 4: Biological Evolution						
	Extension Topic: Impact of Climate Change						
H2 biology	Core Idea 1: The Cell and Biomolecules of Life	A. Organelles and Cellular Structures	B. Biomolecules of Life and Cellular Transport	*C. Proteins*	*D. Stem Cells*		
	Core Idea 2: Genetics and Inheritance	A. The Structure of Nucleic Acids and Gene Expression	B. Organisation of Genomes	C. Control of Gene Expression	D. DNA Mutations	E. The Cell Cycle	F. Inheritance
	Core Idea 3: Energy and Equilibrium	A. Transformation of Energy between the Environment and Organisms	B. Communication and Equilibrium Organisms				
	Core Idea 4: Biological Evolution	A. Natural Selection and Adaptation	B. Evolution and Biodiversity, Species and Speciation				
	Extension Topic A. Infectious Diseases						
	Extension Topic B: Impact of Climate Change on Animals and Plants						
H3 biology	Additional Content	The additional content in the MOE-H3 Biology syllabus is organised into the four Core Ideas and two Extension Topics, which correspond to those in the syllabus for H2 Biology. Within each of these Core Ideas or Extension Topics, information is organised into: 1. Narrative 2. Guiding Questions 3. Learning Outcomes					

		The Guiding Questions are open-ended, as they are meant to make connections between topics/concepts and reveal the underlying threads and unifying themes of the H2 content. The Learning Outcomes list the specific content of the H3 syllabus. H2 Learning Outcomes are not listed but are all assessable as part of the H3 assessment. See the H3 biology syllabus for the narratives and tables displaying guiding questions and learning outcomes for each of the Core Ideas and Extension Topics.[123]

[123] MOE, Singapore. (2021). *Biology Syllabus. Pre-University. Higher 3. Syllabus 9816.*

Structure

DP biology is taught over two years, whereas the SGA curriculum is designed to be completed over two or three years, depending on the type of institution the student attends. Students choose to study H1 or H2 based on their ability, interest and potential future careers. H1 is 'designed to broaden students' learning that will support the development of scientific literacy'.[124] The H1 syllabus is focused on equipping students with the skills they need to make 'informed decisions based on sound scientific knowledge and principles'[125] so that they become citizens that can contribute positively to society. The H2 curriculum is intended to suit students who enjoy science and are capable of studying it at a deeper level than H1, laying 'a strong foundation of knowledge, skills and attitudes' in order to 'prepare students well for university, work and life in the future'.[126] For students who wish to extend their science skills and deepen their understanding, they may study H3 in addition to H2. The H3 syllabus is 'designed to build on and extend the knowledge, understanding and skills acquired from the H2 biology syllabus', catering to 'students of strong ability and keen interest in biology', and being 'designed with a strong emphasis on independent and self-directed learning'.[127] As such, the H3 syllabus goes into more depth than H1 and H2 and is intended to be a more challenging subject

Both the DP and H1 have four over-arching topics in which there are several sub-topics. The DP contains an 'experimental programme', whereas H1 contains an 'Extension Topic' and H2 contains two 'Extension topics'. The DP has categorised content further into four areas within each overarching topic, whereas H1 and H2 do not have this level of organisation in the curriculum. H3 has four over-arching topics which are referred to as 'Core ideas' and contain only one topic within them, unlike the multiple sub-topics in the DP. H3 contains two 'Extension topics' compared to the DP's 'experimental program'. If completing H3, students are expected to complete both extension topics as these require students to 'demonstrate the assimilation of the Core Ideas and extend their knowledge and understanding to real-world challenges'.[128]

Although H3 biology structure appears somewhat more simplistic than the DP, it is designed in a way that develops students' ability to think deeply, laterally and critically, as well as integrate knowledge and skills from different areas of the biology syllabus. The SL and HL content within the DP are clearly defined and separated, with AHL sub-topics for students studying HL. Due to the design of the SGA, instead of offering one course with SL and AHL content, SGA offers three subjects which each have a separate syllabus. It is expected that students will cover all content of whichever route they choose to study. Moreover, the DP outlines suggested teaching time to be allocated to both SL and HL content, while the SGA curricula does not contain this information. This may be due to the flexibility within the SGA, where students may spend either two or three years studying this course (depending on what type of institution they study in) and therefore the time devoted to each topic may vary.

[124] MOE, Singapore. (2020). *Biology syllabus Pre-University Higher 1.* p.1.
[125] Ibid.
[126] MOE, Singapore. (2019). *Biology syllabus Pre-University Higher 2.* p.1.
[127] MOE, Singapore. (2021). *Biology syllabus Pre-University Higher 3.* p.3.
[128] Ibid. p.7.

Content Alignment

To complement the analysis, the figure below represents a simplified summary of the SGA's content alignment, at topic-level, with DP biology (SL and AHL content). Following this figure is a table highlighting significant SGA content that is not in the DP.

Figure 25: Summary of the content alignment the SGA biology H1, H2 and H3 has with the main topics of the DP biology

DP biology topics	SL Presence in H1	AHL Presence in H1	SL Presence in H2	AHL Presence in H2	SL Presence in H3	AHL Presence in H3
A Unity and Diversity						
1 Molecules						
2 Cells						
3 Organisms						
4 Ecosystems						
B Form and Function						
1 Molecules						
2 Cells						
3 Organisms						
4 Ecosystems		N/A		N/A		N/A
C Interaction and Independence						
1 Molecules						
2 Cells						
3 Organisms						
4 Ecosystems		N/A		N/A		N/A
D Continuity and Change						
1 Molecules						
2 Cells						
3 Organisms						
4 Ecosystems						
Experimental programme						

* Where applicable, content alignments found in pre-requisite subjects are carried forwards and combined with new alignments to represent the cumulative content covered.

Key:

	Strong presence of this topic in the SGA.		*Partial presence of this topic in the SGA.*		*Little or no presence of this topic in the SGA.*	N/A	*This topic does not exist at the respective level.*

Table 24: SGA biology content which is not covered in the DP

Significant Singapore content which is not included in DP biology*		
H1	**H2**	**H3****
• Induced pluripotent stem cells and their use • Mosquitoes (Aedes aegypti), malaria and dengue	• Induced pluripotent stem cells and their use • Mosquitoes (Aedes aegypti), malaria and dengue	• Genetic engineering

*Significant content does not include topics that are typically studied *prior* to upper secondary.

**Content listed in this column is specific to H3. As H2 is always studied alongside H3, topics in the H2 column should be considered in addition to the topics in this column.

H1 biology

The H1 curriculum has noticeably less breadth than the DP when it comes to both SL and AHL content, with alignment being observed in only some areas within each DP biology topic. As to SL content specifically, topics A – Unity and Diversity and C – Interaction and Independence have only one sub-topic that aligns with the Singaporean curriculum, while the sub-topics covering organism and ecosystems are absent from topic B – Form and Function.

The H1 curriculum has the highest alignment with topic C – Continuity and Change, with all SL content being covered, even if generally partially. Some AHL content in this topic is also partially covered, though the depth is not comparable, and coverage of AHL content in all other topics is absent.

Overall, neither the depth nor the breadth of the H1 curriculum are comparable to that of either SL and HL. There are some topics found in the H1 curriculum that are not present in the DP: induced pluripotent stem cell and their use; a species of mosquito (*Aedes aegypti)*; and the incidence of malaria and dengue. Within the SGA curriculum, there is great emphasis on cancer as they state in the syllabus: 'cancer has a much higher incidence in Singapore compared to other diseases and accounts for as much as 30 percent of deaths in this country'.[129] It is therefore of national interest to them to educate students in the disease so that perhaps they can contribute to researching treatments. Singapore also put significant emphasis on the *Aedes aegypti* mosquito in the context of not only how it spreads malaria, but also how disruption of ecosystems and deforestation allows for the survival of species that are far more effective at transmitting dengue.[130] The limited alignment with the DP may be linked to the focus given to these aspects. Added to this is that much of the content of H1 is presented at the level of prior learning to upper-secondary biology. This reiterates the fact that H1 is designed to provide a base level of knowledge and understanding, rather than in-depth knowledge and challenge.

H2 biology

The H2 curriculum contains a higher number of DP topics within it than the H1 and, as seen in the content alignment summary figure above**,** the topic coverage is slightly more aligned with the DP. While topic A – Unity and Diversity is still not covered to a great extent, topics B – Form and Function, C – Interaction and Independence, and D – Continuity and Change show increased coverage when compared to H1.

This is particularly true when it comes to AHL content – while in H1, only a limited number of AHL sub-topics within topic D was partially covered, in H2 there is strong alignment with the AHL content on molecules within topic C – Interaction and Independence, and a number of additional partial alignments with other AHL sub-topics, namely: cells within A – Unity and Diversity; molecules and cells within B – Form and Function; cells within C – Interaction and Independence.

Thus, both the depth and breadth of the H2 curriculum align more closely with the DP than the H1 curriculum. There are areas of the curriculum that are not covered by the DP which could account for some of the gaps. For example, within topic A – Unity and Diversity content. H2

[129] MOE, Singapore. (2020). *Biology syllabus Pre-University Higher 1.* p.17
[130] Ibid. p.23

devotes some time to induced pluripotent stem cells, cancer and the *Aedes aegypti* mosquito for reasons discussed above, but H2 also puts emphasis on vaccination, specifically in the context of Tuberculosis (TB). The H2 curriculum states that 'Although successful vaccination programmes in Singapore have kept [tuberculosis] under control, there have been new cases appearing in the population'.[131] Again, the SGA demonstrates tailoring of the curriculum to reflect issues within Singapore.

H3 biology

When taking H2 and H3 combined, the breadth of content is slightly higher, but not substantially so. If compared to the DP at SL, aspects of all main topics are covered and, as expected, some to a greater extent than H2. However, the alignment with AHL content is still very similar to that between AHL and H2, with increased coverage observed mostly around molecules within topic B – Form and Function. There are a number of gaps where there is no real alignment between the DP and H3, particularly in the topic A – Unity and Diversity. The focus of the H3 is on analytical skills, critical thinking and linking concepts and ideas from multiple areas of the curriculum. There are topics that are present in H3 but not in the DP; as well as topics previously discussed (cancer, mosquitoes and vaccination) H3 also includes genetic engineering and cloning. These areas take up a considerable amount of the H3 curriculum.

Summary

As the SGA curriculum progresses from H1 to H3, the alignment with the DP in both breadth and depth increases with the level – being lowest at H1 and highest at H3. The SL content in topic D – Continuity and Change is well-covered in each syllabus, but topic A – Unity and Diversity is almost entirely absent from all. A large part of topic A for the DP is the study of the properties of water, which is not covered by any of the SGA curricula. The organisms covered within B3 organisms – centred around human biology topics such as circulation, musculoskeletal system and gas exchange, as well as transport in and structure of plants – is also absent from all SGA curricula. The SGA curricula also put more emphasis on 'real-world' aspects of science, such as the effect of climate change and the incidence of cancer, as these topics align with Singapore's priorities as a country. The experimental programme of the DP is highly aligned with all SGA curricula, within the section of the curriculum entitled 'demonstrating science inquiry skills'[132] it describes in detail how students are expected to plan and conduct investigations, obtain, analyse and evaluate their data and then communicate their findings. Although it is not explicit whether this is collaborative or independent work, the principles of the experimental programme are clearly within H1, H2 and H3 SGA biology.[133]

5.4.3 Demand – Biology

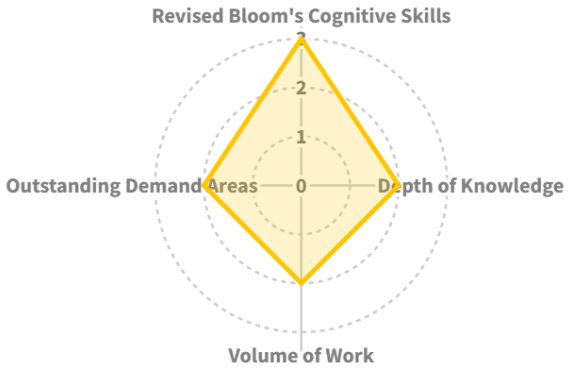
The DP and SGA curricula were analysed using the same demand tool in order to create a demand profile for DP biology SL, DP biology HL, H1 biology, H2 biology, and H3 biology. These demand profiles are presented below in the form of radar diagrams, with superimposed diagrams also being featured to enable immediate visual comparison.

[131] MOE, Singapore. (2019). *Biology Syllabus Pre-University Higher 2.* p.33

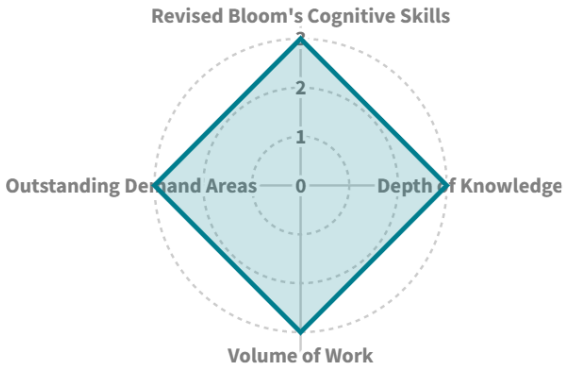
[132] MOE, Singapore. (2020). *Biology syllabus Pre-University Higher 1.* p.4; MOE, Singapore. (2019). *Biology Syllabus Pre-University Higher 2.* p.6; MOE, Singapore. (2021). *Biology syllabus Pre-University Higher 3.* p.5

Figure 26: Visual representations of subject demand

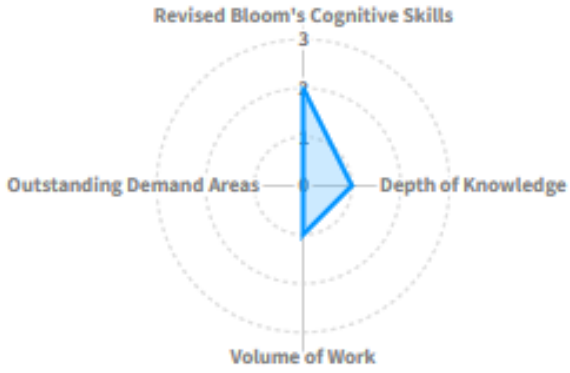
DP biology SL



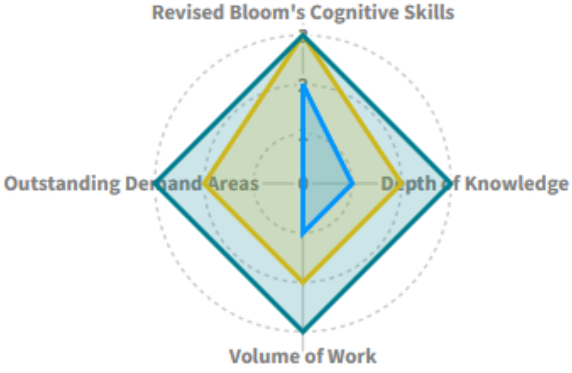
DP biology HL



SGA H1 biology

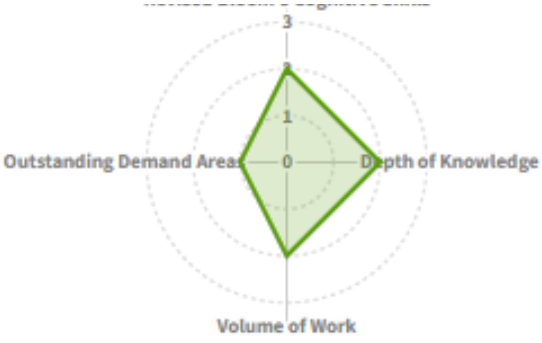


DP and SGA H1 biology



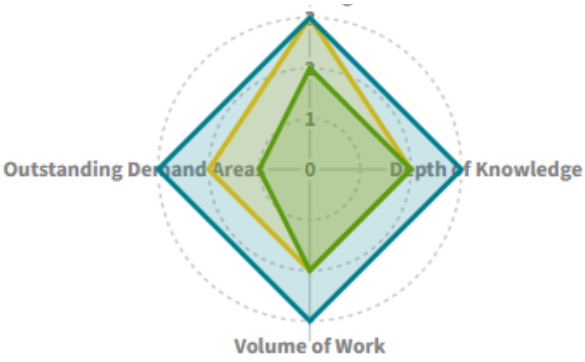
SGA H2 biology

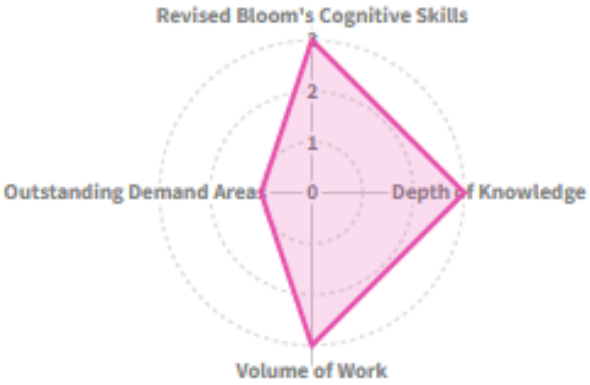
SGA H3 biology

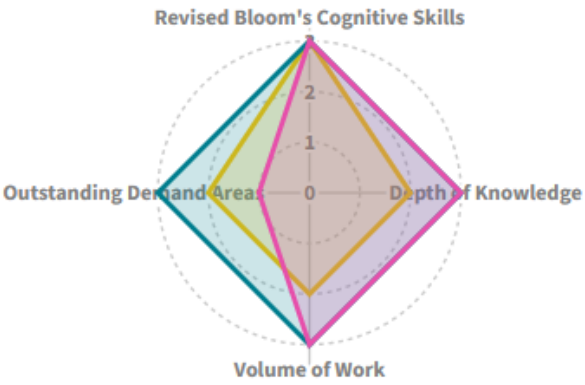


DP and SGA H2 biology

DP and SGA H3 biology







The panel of experts carried out a detailed analysis of each course and reached a consensus on the scores shown in the profiles above. The following points were particularly important within the panel discussion:

- Regarding the scores for **Bloom's Cognitive Skills**:
  - DP biology has the same learning outcomes for both SL and HL, meaning that these scores are the same. These were judged to merit a score of 3 due to the high levels of critical thinking, critical awareness and elements of synthesis and creation present in the majority of aims and Assessment Objective 3.
  - A score of 2 was given to H1 biology as, while there is some evidence of analysis and synthesis in the learning outcomes, the predominant focus of both outcomes and assessment objectives is on knowledge and understanding, with some evidence of application and evaluating. H2 biology has more opportunities for higher order cognitive skills, with some opportunities for evaluation. However, the latter is not the predominant focus and, when compared with H2 physics and chemistry, H2 biology places less emphasis on the application of knowledge to the wider world – thus, a score of 2 was deemed appropriate. For H3 biology, a score of 3 was awarded given the numerous references to higher order thinking skills, including problem solving and synthesis.

- Regarding the score for **Depth of Knowledge**:
  - DP biology SL was deemed to merit a score of 2 for depth of knowledge due to the pre-requisite skills and competences (e.g. interpretation of graphs data, mathematics skills, some chemistry and geography links) required to access the course, as well as the moderate to high level of cognitive complexity of the knowledge that students are expected to acquire. As to the HL course, the greater depth and additional opportunities provided for extended thinking in the additional higher level option topics pushed the score to a 3.
  - Within H1 biology, whilst there is mention of 'discussing ethical implications' as evidence of some higher order thinking skills, a lot of the content was found to be basic and typical of pre-upper secondary curricula – which awarded it a score of 1 for depth. For H2, a score of 2 was given as students are consistently encouraged to think about the 'whys' of what they are learning. Even though some of the subject

content does not lend itself to extension, the way it is being understood and discussed by students within their lessons requires a certain level of depth of knowledge and understanding. H3 biology, studied in addition to H2, covers topics in great detail and features multiple areas requiring extended thinking within and across topics, being awarded a score of 3.

- Regarding the scores for **Volume of Work**:
  - DP biology SL was judged to comprise a moderate-heavy workload (a score of 2) as students are exposed to multiple biology topics, with each topic being allocated a standard to short amount of time. The volume demands of the HL course, on the other hand, were found to be sufficient to meet a score of 3 – even though the proportion of topics per allocated teaching hour is smaller, these topics are covered in great depth and with a focus on application.
  - H1 biology was awarded a score of 1, as the content is relatively simple and having one to two years of teaching time to cover it suggests that a lot of time can be spent on each topic. H2 curriculum provides more challenge for students as it is designed to take students' learning further. H2 is studied over a longer period of time – two to three years – but it features a higher number of challenging topics and skill development; hence the score of 2. H3 biology received a score of 3 as students must study it concurrently with H2; therefore, within the same two-three year timeframe, students are not only covering a higher number of topics, but also doing so at a greater depth, making the volume of work high.

- Regarding the scores for **Outstanding Areas of Subject Demand**:
  - For the DP biology SL course (awarded a score of 2), the scientific investigation research project that students need to undertake, the linking questions outlined in the syllabus and the collaborative science project were considered to be areas of stretch. In addition to the latter, the HL course features additional higher levels topics which were deemed to include additional areas of stretch, meriting a score of 3.
  - No stretch areas were found in H1 biology, hence the score of 0. H2 was given a score of 1 for stretch areas due to the requirement for synthesis and cross-area links (e.g. the requirement to investigate how climate change affects the global food supply), as well as the practical investigation aspect. H3 biology includes a few subject-content areas of outstanding subject demand, such as mitochondrial eve and prions. These, combined with the challenge offered by the design of the course itself – which aims to extend and deepen students' knowledge across multiple topics – amounted to two areas of stretch, awarding it a score of 1 for stretch.

6. Key Findings

This section summarises the alignment and main similarities and differences found between the DP and the SGA, both at programme level and subject level.

6.1 Programme Level

Philosophical Underpinnings

All the key themes within the IB's learner profile, ATL, and philosophy of international-mindedness are present in the SGA's curriculum philosophy, desired outcomes of education and Framework for 21st century competencies. Although there are some differences in degree of emphasis on specific issues, students or teachers moving between the programmes would find a high level of consistency between the two.

Programme Structure

Both programmes share a similar range of disciplines in languages, humanities, the arts, mathematics and sciences. In addition, both also offer compulsory skills-based components aimed at promoting holistic development – i.e. the TOK and CAS in the DP, and the KI and 'life skills' curriculum in the SGA. Moreover, both programmes offer students the option to study most subjects at different levels – the DP offering them at both SL and HL, and the SGA offering subjects at least at H1 and H2 (with option to study some at H3).

Although the SGA does not follow a strictly baccalaureate-style approach like the DP, it does encourage some breadth of study by requiring students to take five different content-based subjects, with at least one subject from a contrasting discipline and a requirement to study the mother tongue course at H1 (at least).[134] Additionally, the two programmes may also be similar in terms of duration, although this depends on the type of educational institution a student goes to – if studying at a junior college, the programme will be completed in two years, the same duration as the DP. However, if studying at the millennia institute, the SGA programme will last three years, which allows students more time to prepare for their A Level examinations.

Entry Requirements

Both the DP and the SGA present somewhat flexible approaches to entry requirements at the start of their programmes. The IB encourages students and teachers to consult subject guides around expected prior learning but does not provide fixed entry requirements. There are also different pathways which can lead to taking the SGA. Students may study O Levels at the end of their secondary education or be on an Integrated Programme that spans both secondary and pre-university education without requiring O Level examinations.[135] Schools such as junior colleges and the millennia institute set out formal entry requirements in the form of admissions criteria. These are based on O Level results, including L1R5 and L1R4 scores for JCs and MI

[134] In the context of the SGA, a contrasting discipline is a subject that belongs to the opposite subject group to the subject group a student is specialising in – i.e. a subject from the 'Humanities and the Arts' group if the student is taking mostly 'Mathematics and Sciences' courses, and vice versa.
[135] MOE, Singapore. (2022). *Post-secondary Education Booklet*.

respectively, as well as grade requirements for specific subjects.[136] Bonus points are also available for attainment in co-curricular activities, language grades, and school affiliation.

Student Learning Pathways

Both programmes provide a significant level of optionality in relation to subjects studied, both require students to study subjects from different subject groups, and both provide opportunities for students to expand learning in specific subjects of interest, allowing up to four subjects to be studied at higher level.

Overall, it is possible for SGA students to take a pathway that is very similar to the DP, studying a similar breadth and depth of subjects. The key difference between the two programmes' learning pathways is that, depending on students' choices, pathways may be more specialised in the SGA than the DP. The reason for this is that, unlike the DP, the SGA does not require students to study one subject from each subject group. Thus, SGA students may choose to specialise in one broad area (e.g. the sciences, humanities, or languages) by studying up to four subjects from that area, an option that is not available in the DP. This being said, the DP does offer a non-regular diploma pathway to some students, allowing them to study three sciences and achieve a similar degree of specialisation as that permitted in the SGA.

Assessment Methods

The DP and SGA share similar approaches to assessment. Both programmes use external assessment as the main mode of assessment, deploying multiple formats in both, including written, oral, performance, or in electronic format. Moreover, many of the same question types are used by both programmes, including short response, extended response, multiple choice, real-world contexts, and experiment-based questions. In both, optionality is rarely used, though it does appear in some papers. Duration of external assessment is also similar between the two programmes.

The largest difference between the two programmes is with regard to internal assessment. Whereas the DP has internally assessed components in its subjects, the SGA does not. Despite this, a high level of alignment is still observed between the two programmes when it comes to assessment, given that internal assessment only accounts for 20% of the grades in DP mathematics and science subjects.

Summary

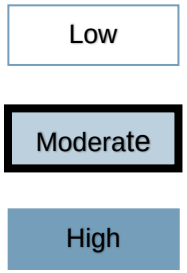
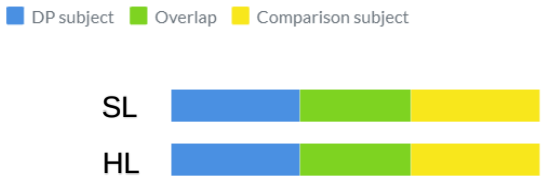
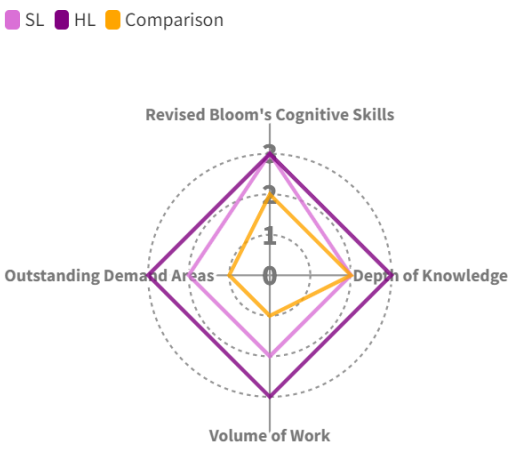
The entry requirements of the two programmes and the student learning pathways are the most significant points of difference and the philosophical underpinnings and assessment methods are the most significant points of similarity. In respect to programme structures, there are some notable differences, though with points of clear alignment with regard to how students would be likely to experience the programmes in practice.

[136] MOE, Singapore. (2022). *Joint Admissions Exercise (JAE)*. Available from: (Joint Admissions Exercise (JAE): Admission criteria | MOE

6.2 Subject Level

This section provides visual summaries of the subject-level alignment between specific subjects within the DP and the respective comparison points in the SGA. The summaries include key findings on learning outcomes alignment, content alignment and demand alignment, as per the key below:

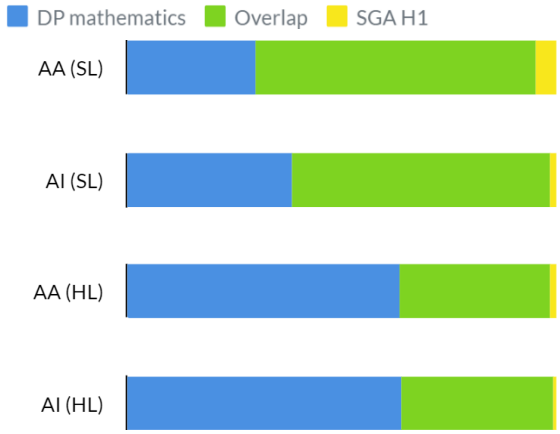
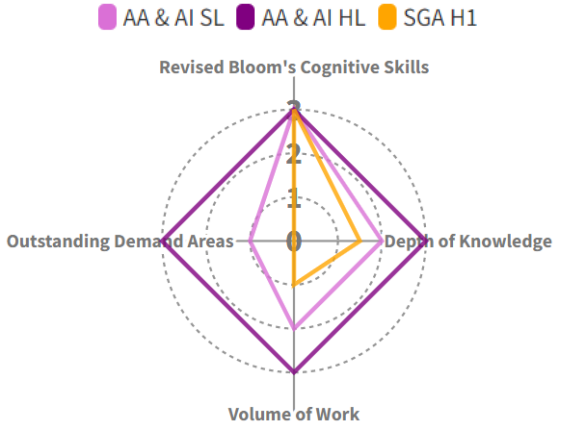
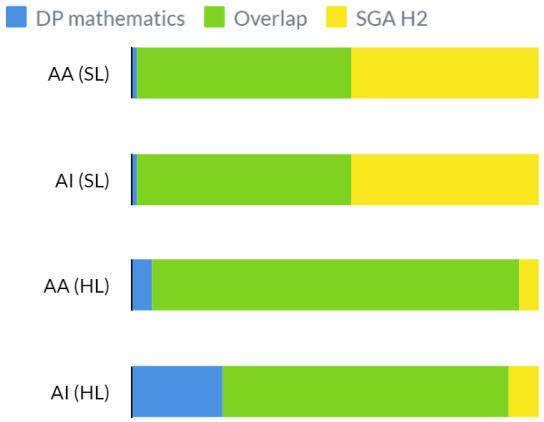
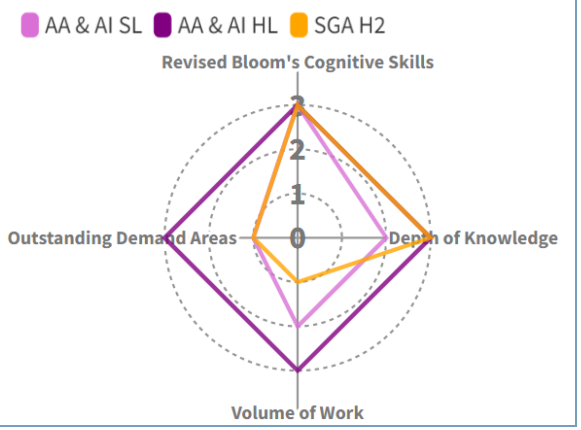
Key:

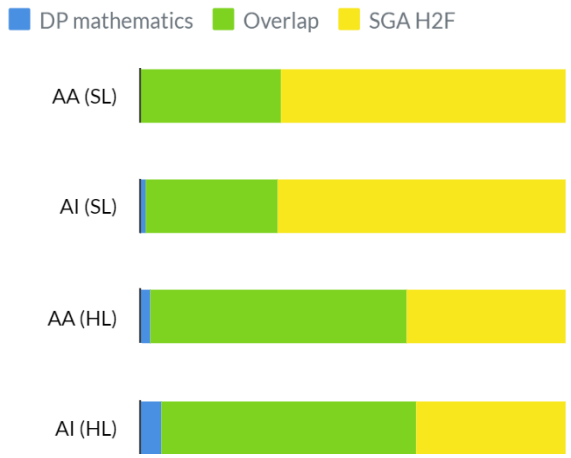
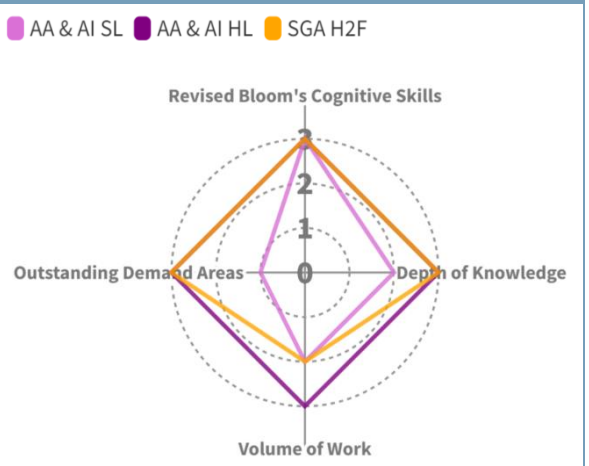
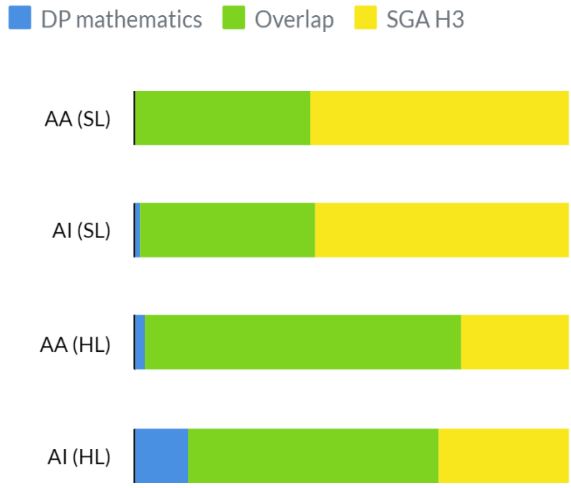
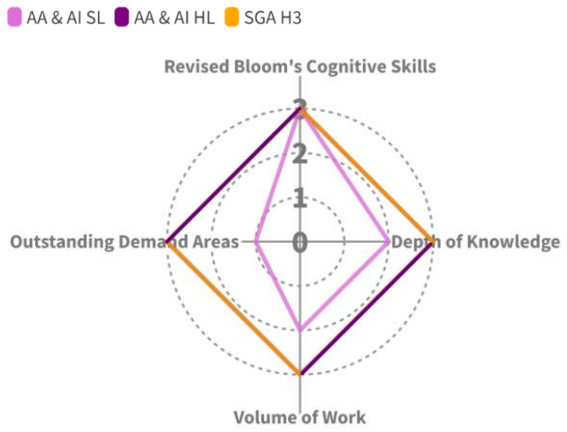
Subject name	Learning outcomes alignment	Content alignment	Demand alignment
Displays the name of the comparison subject	 This represents the learning outcome alignment between the DP subject and the comparison subject. A black border is placed around the selected judgement – 'Moderate' in this example.	 These bars represent the content alignment between the DP subject and the comparison. There is one bar showing alignment with SL content and another for HL content (inclusive of SL content). The **green** section of the bar represents the overlap of content between the subjects. The **blue** section represents content which was in the DP subject only. The **yellow** section represents content which was in the comparison subject only. Therefore, if, say, the blue section was longer than the yellow, this can be interpreted as DP subject having more content unique to itself than the comparison did. A large green bar would indicate that a substantial proportion of content overlaps between the DP and the comparison subject.	 This radar diagram displays the demand judgement scores for the comparison subject(s) and the DP subject – both SL and HL.

6.2.1 Mathematics Alignment

The subject level alignment between the DP and SGA mathematics subjects is represented below:

Figure 27: Visual representations of subject-level alignment (mathematics subjects)

Subject name	Learning outcomes alignment	Content alignment	Demand alignment
H1 mathematics	Low Moderate **High**		
H2 mathematics	Low Moderate **High**		

Subject name	Learning outcomes alignment	Content alignment	Demand alignment
H2F mathematics	Low Moderate **High**		
H3 mathematics	Low Moderate **High**		

- **Learning outcomes alignment**: the level of alignment between both DP mathematics subjects, at both SL and HL, and the SGA courses' learning outcomes is significant, as nearly all DP themes are present in the SGA curricula.

- **Content alignment**: the level of content alignment between DP mathematics subjects and SGA courses varies. For H1, there is reasonable alignment with DP SL, though the former has less content than the latter, and significantly less than DP HL. There is strong alignment between H2 mathematics and AA HL, as the majority of content is overlapping. There is slightly less, but still considerable, alignment between H2 and AI HL. When considering H2F in addition to H2, these have a greater breadth and depth of content studied compared to DP HL subjects. Similarly, when H3 is offered with H2, the content of DP HL is exceeded – though through depth and practice of rigour, rather than breadth. Overall, the content within H1 and H2 is very similar to the DP curriculum, with H2 being of comparable size to DP HL, whereas the content of H2F and H3 goes beyond the scope of what is offered in the DP.

- **Demand alignment**: SGA H1 is surpassed in most demand categories by both DP SL and HL. SGA H2 scores similarly to DP HL for depth of knowledge, but its lower scores for outstanding areas and volume mean that it is generally more similar to the demand of DP SL. H2F and H3 demand scores are very comparable to DP HL subjects, scoring highly for cognitive skills, depth, volume, and outstanding areas of demand.

The **key similarities** identified were the following:

- **Similarities in learning outcomes**: seven out of the eight themes extracted from the DP are strongly present in the SGA curricula, hence there is high alignment in the mathematics learning outcome themes between the DP and SGA. Both detail a wide range of skills to be developed, which altogether demonstrate a holistic approach. Indeed, it is important to both the DP and SGA that students not only learn mathematical skills, but also cultivate a genuine interest and appreciation of the beauty of mathematics, whilst also learning transferable skills, such as reflective working, collaboration, independence, confidence, and perseverance. In addition to this, themes of understanding and application, problem-solving, reasoning, making links, communication, and technology are all present in the DP and SGA. Furthermore, it is an aim in both curricula that students will be able to use the skills and understanding learnt in their mathematics courses to engage with local and global events and issues, thus preparing them for society.

- **Similarities in content**: the key similarity in the structure of content between the DP and SGA is the distinction of different levels which students can choose from – SL/HL for DP and H1, H2, H2F, H3 for SGA. Generally, H1 content is similar to DP SL subjects, covering similar concepts in the areas of functions, statistics and probability, and calculus. However, H1 has somewhat less breadth and depth than the DP SL, and therefore they can be considered moderately, rather than highly, aligned. Like AI, H1 has a higher focus on applied mathematics, with the largest content area being 'Statistics and Probability'. H2 is very similar to DP HL subjects, with slightly more alignment with AA than AI content, especially for AHL topics. A high number of SL and

AHL topics is present in H2, which has comparable breadth and depth to DP HL subjects.

- **Similarities in demand**: DP and SGA both have the highest score for the presence of higher-order cognitive skills (taken from Bloom's Revised Taxonomy) and therefore place similar emphasis on analysis, evaluation, and creation in their learning outcomes. For the rest of the categories, H2F and H3 score the same, or similarly, to DP HL subjects, hence these subjects are highly aligned in terms of demand. H2 scores the same as DP HL subjects for depth but is closer to SL for volume and outstanding demand areas.

The **key differences** identified were the following:

- **Differences in learning outcomes:** though the SGA details outcomes that are applicable to all courses through its 21CC and MCF, unlike the DP it also outlines course-specific outcomes via 'syllabus aims'. Thus, though all courses present themes similar to the DP, the syllabus aims of H2F and H3 describe some of the more advanced skills within these themes, which are not explicit in the DP. Most significantly, H3 describes 'advanced problem-solving, mathematical rigour, and a focus on writing and evaluating proofs'. Furthermore, a few different themes and skills to those in the DP emerge from the MCF. For instance, the SGA goes further to encourage the monitoring of thinking processes and self-regulating learning, as it includes 'metacognition' as one of its five components. Moreover, the MCF is generally more prescriptive and lists a higher number of specific skills, including heuristics and spatial visualization. The prescriptive nature of the MCF means that some skills, such as modelling, have a higher emphasis in the outcomes of the SGA than in the DP. Finally, despite there being a strong presence of DP themes in the SGA, the theme of using inquiry-based approaches is not explicitly present in the outcomes of the SGA, though some of the same skills necessary for this approach are mentioned in the MCF and inquiry-based learning is present in the 'Teaching Processes'.

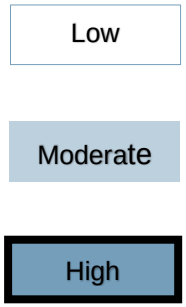
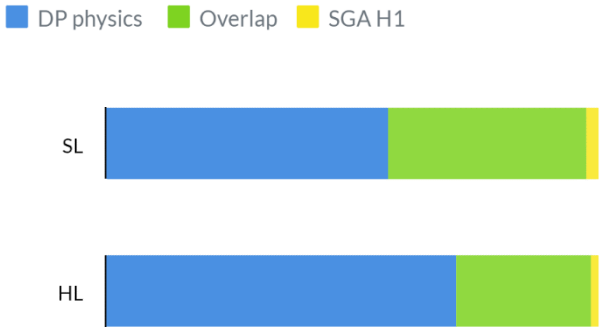
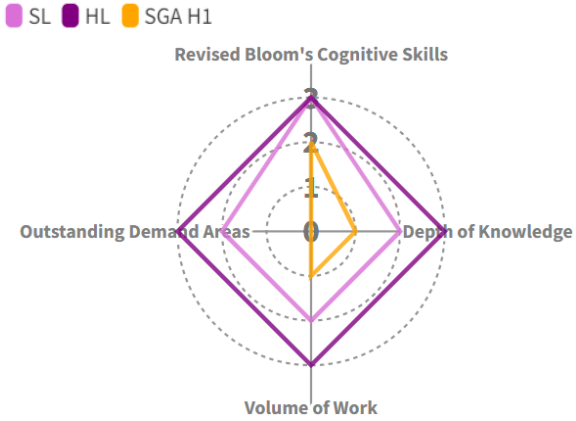
- **Differences in content:** there are several differences in the structure of mathematics content, as the SGA offers more opportunities for advanced mathematical study through H2F and H3. Also, whereas HL content builds on SL, H2 builds on O Level Additional Mathematics, not H1. With regard to main areas covered, a significant difference is that topics related to geometry and trigonometry, excluding vectors, are covered in learning prior to A Level, the depth of which depends on whether Additional Mathematics is taken. For content alignment, though the first two levels, H1 and especially H2, have similarities with the DP courses, there are larger differences with regard to H2F and H3. Despite some H2F topics being identifiable in the DP HL syllabi, the former goes into more depth in these topics and includes more complex concepts. In addition to this, H2F includes many topics which are not in the DP, and generally covers a wider range of advanced mathematical topics than any single DP HL subject; thus, SGA students taking this course will experience greater depth and breadth than DP students studying HL. Another key difference is the content of H3, which is tailored for students who specifically intend to study mathematics at university and focuses on mathematical results, rigour, and proof to a far greater extent than DP subjects.

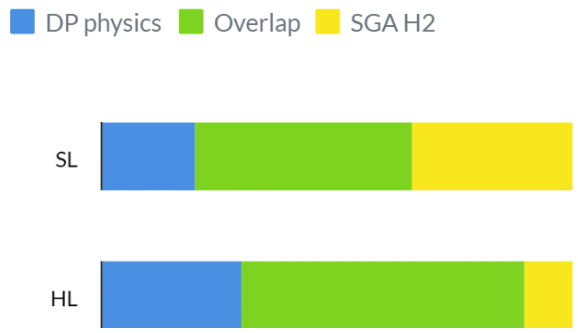
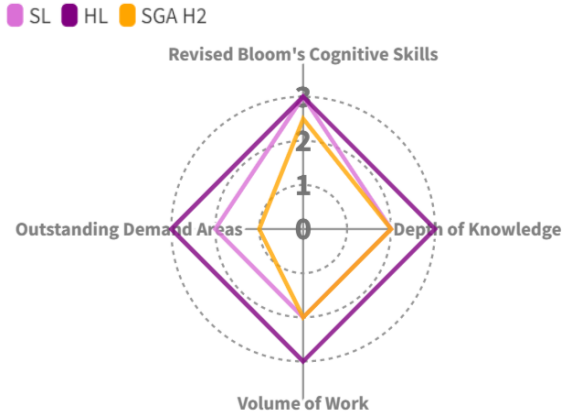
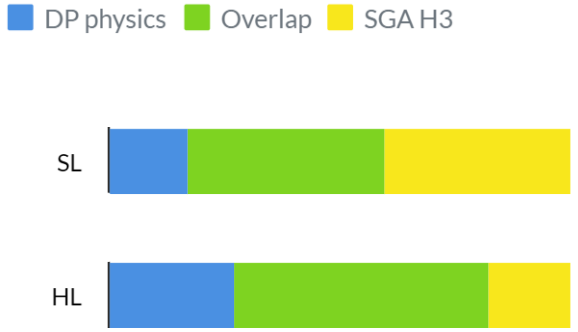
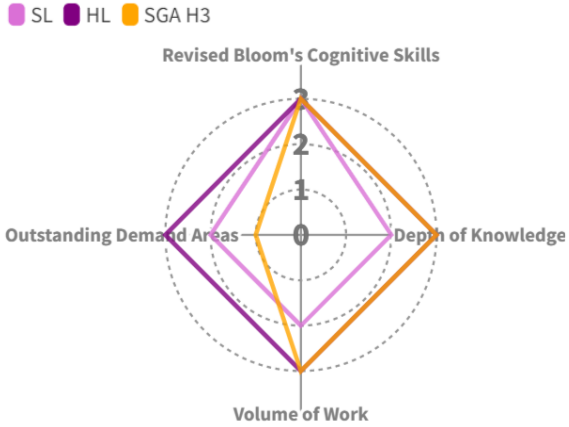
- **Differences in demand:** for demand, the least aligned subject with the DP is H1, which scores less than DP SL in all categories except Bloom's cognitive skills. Furthermore, for both H1 and H2, the most significantly different demand category is volume of work, with this being judged as a standard (rather than heavy) amount for these courses. Moreover, though this judgement is based on a two-year duration, it can be noted that students taking these subjects in the millennia institute will have an extra year for study.

6.2.2 Physics Alignment

The subject level alignment between the DP and SGA physics is represented below:

Figure 28: Visual representations of subject-level alignment (physics)

Subject name	Learning outcomes alignment	Content alignment	Demand alignment
H1 physics			

Subject name	Learning outcomes alignment	Content alignment	Demand alignment
H2 physics	Low Moderate **High**		
H3 physics	Low Moderate **High**		

- **Learning outcomes alignment**: the level of alignment between the learning outcomes of DP and SGA physics is significant, with nearly all themes extracted from the DP learning outcomes being present in the SGA's learning outcomes.

- **Content alignment**: H1 content lacks the breadth and depth to be comparable to either SL or HL, though it does have significant overlapping content with certain SL topics. H2 has a similar breadth to DP physics and somewhat surpasses SL in terms of depth, though only with the addition of H3 is the depth comparable to that of DP HL. All SGA subjects, especially H2 and H3, have some sub-topics which are not in the DP, and slightly differ in their coverage of certain sub-topics. Finally, the SGA subjects have alignment with the DP's experimental programme, as practical work and scientific inquiry are featured in all of them.

- **Demand alignment**: H1 is surpassed in all demand categories by both SL and HL, whereas H2 and H3 score similarly to DP SL and DP HL, respectively.

The **key similarities** identified were the following:

- **Similarities in learning outcomes:** SGA physics covers most of the DP learning outcome themes. Conceptual understanding, techniques that characterise science, and an awareness of local and global problems are strongly emphasised within physics in both programmes. Like the DP, the SGA also places importance on creativity and critical thinking within its learning outcomes, as well as skills for scientific inquiry.

- **Similarities in content:** H2 and H3 have considerable alignment with the DP curriculum, covering nearly all SL topics and a significant number of HL topics. H3 is comparable to DP HL in terms of breadth and depth and H2 is comparable in breadth to the DP SL, though the former features more depth than the latter in certain topics. Throughout all SGA subjects, there is strong alignment with SL topics A. Space, time and motion and D. Fields. Regarding AHL content, H2 and H3 align particularly strongly with E. Nuclear and quantum physics.

- **Similarities in demand:** The DP and H3 physics have the highest score for the presence of higher-order cognitive skills (taken from Bloom's Revised Taxonomy) as they place similar emphasis on analysis, evaluation, and creation in their learning outcomes. H2 physics has the same scores as DP SL for depth of knowledge and volume of work, thus there is reasonable alignment between DP SL and H2 in terms of demand. As well as Bloom's, H3 has the same scores as the DP HL subject in two additional demand categories: depth of knowledge and volume of work; thus, H3 has reasonable alignment with HL for demand.

The **key differences** identified were the following:

- **Differences in learning outcomes:** there is no mention of the development of technology skills; this DP theme is not found within any area of the SGA physics outcomes. Furthermore, the SGA has less emphasis on collaboration than the DP.

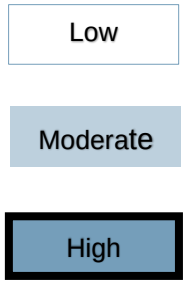
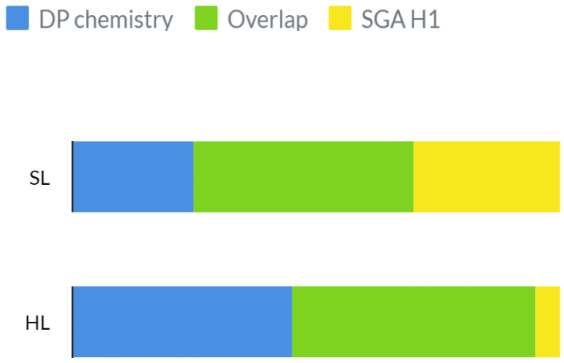
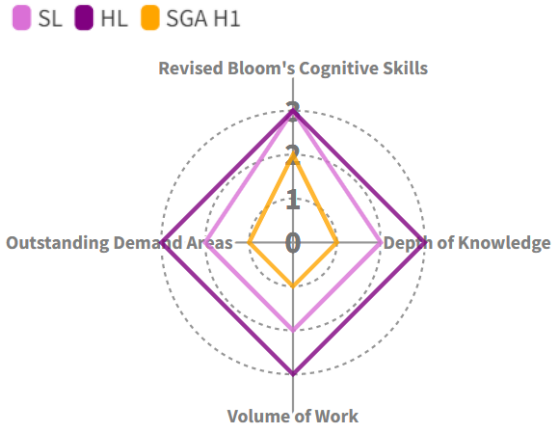
- **Differences in content:** there is considerable DP SL and AHL content that is not covered in H1 physics. The entirety of topic C. Wave behaviour is not found in H1 physics, nor are any alignments found with AHL content. Less significantly, there are a few SL topics which are not present in H2 and H3, these being: B.2 Greenhouse effect, C.5 Doppler effect, E.4 Fission and E.5 Fusion and stars. Regarding AHL content, no SGA subject has alignment with the topics of A.5 Galilean and special relativity, B.4 Thermodynamics, C.5 Doppler effect, D.2 Electric and magnetic fields, and E.1 Structure of the atom. For some sub-topics, the lack of alignment is due to SGA focusing on different concepts. The SGA subjects, most significantly H2 and H3, include some sub-topics which are not present in the DP. These include polarisation (H2), alternating currents (H2), electric and magnetic dipoles (H3), and the use of calculus in capacitors and inductors (H3).

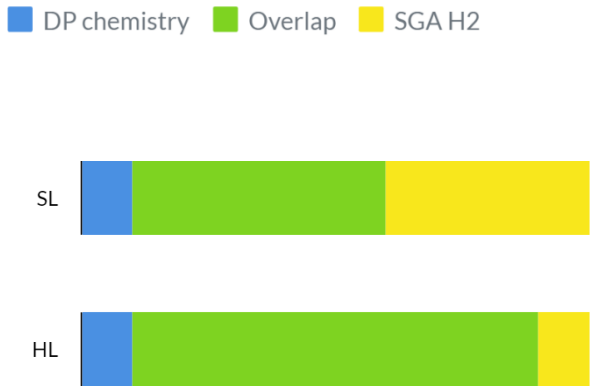
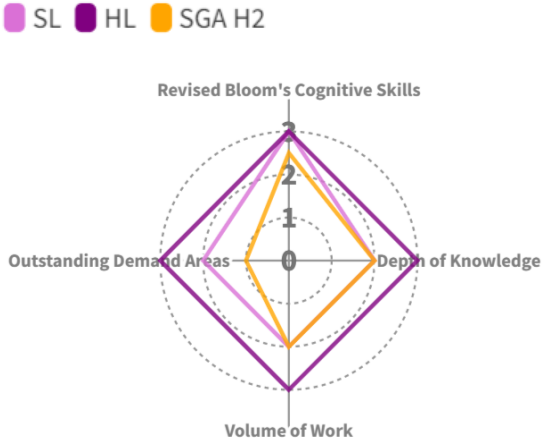
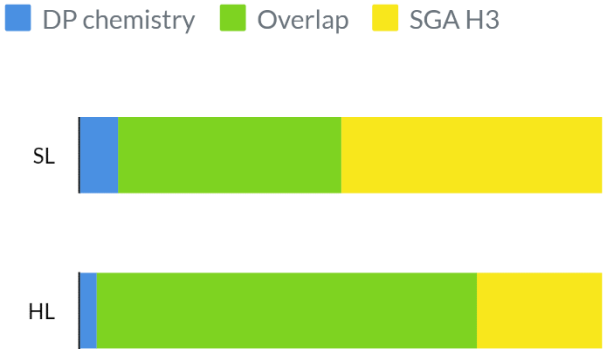
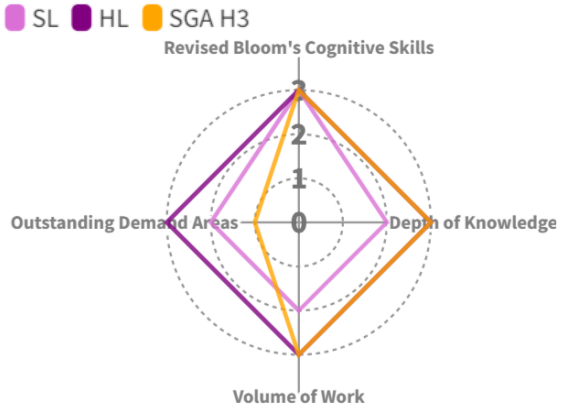
- **Differences in demand:** H1 physics scores less than both DP SL and HL for depth of knowledge, volume of work, and outstanding demand areas, thus it is weakly aligned with the DP in terms of demand. H2 physics has a slightly lower score than both DP SL and HL for the presence of higher order thinking skills and does not match the DP HL in any of the categories, hence it is more aligned with SL than HL for demand. All three SGA physics subjects have fewer outstanding demand areas than the DP and, therefore, consistently score lower in this category.

6.2.3 Chemistry Alignment

The subject level alignment between the DP chemistry and SGA chemistry is represented below:

Figure 29: Visual representations of subject-level alignment (chemistry)

Subject name	Learning outcomes alignment	Content alignment	Demand alignment
H1 chemistry			

Subject name	Learning outcomes alignment	Content alignment	Demand alignment
H2 chemistry	Low Moderate **High**		
H3 chemistry	Low Moderate **High**		

- **Learning outcomes alignment**: the level of alignment between the learning outcomes of DP and SGA chemistry is significant, with nearly all themes extracted from the DP learning outcomes being present in the SGA's learning outcomes.

- **Content alignment**: there is a large amount of overlapping chemistry content between the DP and SGA curricula. H1 includes a significant amount of SL content and is comparable in breadth and depth. H2 covers nearly all SL and HL sub-topics; therefore, there is a high level of alignment and comparability in breadth and depth of study when H2 is studied. Though H3 chemistry covers a few more details from DP HL, alignment overall slightly decreases as H3 covers some topics that are not present in the DP. Finally, the SGA subjects have alignment with the DP's experimental programme, as practical work and scientific inquiry are featured in all of them.

- **Demand alignment**: H1 is surpassed in all demand categories by both SL and HL, whereas H2 and H3 score similarly to DP SL and DP HL, respectively.

The **key similarities** identified were the following:

- **Similarities in learning outcomes:** each SGA chemistry subject available in Singapore covers most of the DP themes. Conceptual understanding, techniques that characterise science and an awareness of local and global problems are strongly emphasised within chemistry in both programmes. Like the DP, the SGA also places importance on creativity and critical thinking and skills for scientific inquiry within its learning outcomes.

- **Similarities in content:** there is significant content overlap between the SGA and the DP chemistry curriculum. H1 includes many of the same topics as SL, as well as a small amount of HL content. Though H1 does not cover all SL areas, and covers some areas in lesser detail, the inclusion of some HL content and sub-topics not found in the DP means that overall it has comparable breadth and depth to DP SL. H2 has very strong alignment with DP HL, sharing most of its content with the latter; thus, the subjects have comparable breadth and depth. H3 includes one or two further HL sub-topics from the DP, plus some sub-topics which are not in the DP. Notably, every Structure and Reactivity sub-topic, both SL and HL, is covered to some extent in the SGA chemistry curriculum, resulting in a high level of content alignment overall.

- **Similarities in demand:** the scores for the presence of higher-order cognitive skills (taken from Bloom's Revised Taxonomy) are the same for the DP and H3 chemistry, as the subjects place similar emphasis on analysis, evaluation, and creation in their learning outcomes. H2 chemistry also has the same scores as the DP SL content for depth knowledge of knowledge and volume of work, thus is of a similar demand level to the DP SL overall. As well as Bloom's, H3 has the same scores as HL in two additional categories: depth of knowledge and volume of work, thus aligning well with DP HL.

The **key differences** identified were the following:

Differences in learning outcomes: there is a distinct absence of the development of technology skills; this DP theme is not found within any area of the SGA chemistry outcomes. Furthermore, collaboration has less emphasis in the SGA than the DP.

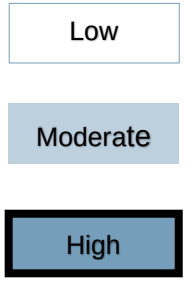
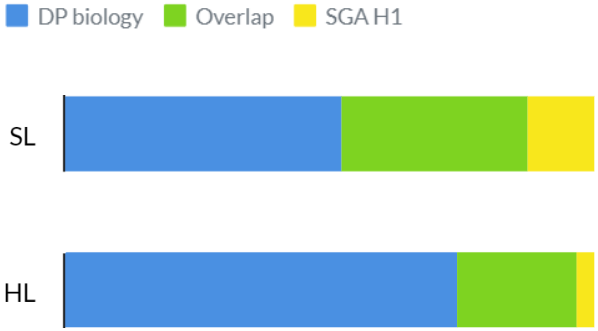
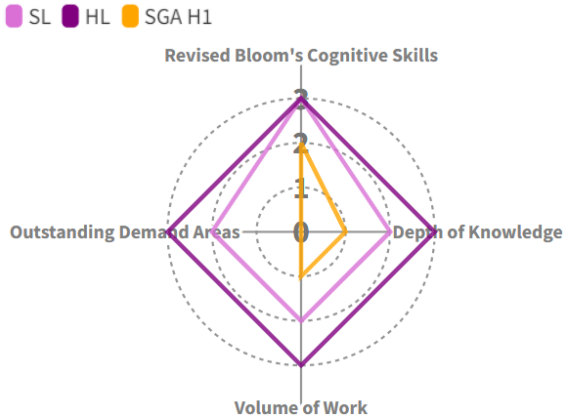
- **Differences in content:** though H1 has similar breadth and depth to the DP SL, it does not share content with the SL topics of Structure 1.5 – Ideal gases, Structure 1.3 – Energy from fuels, Reactivity 3.2 – Electron transfer reactions and 3.3 – Electron sharing reactions. A few sub-topics are also absent from H2 and H3; however, the amount of absent DP content is small. Furthermore, all SGA subjects contain some sub-topics which are not in the DP, such as nanomaterials (H1), elimination (all), and molecular stereochemistry (H3).

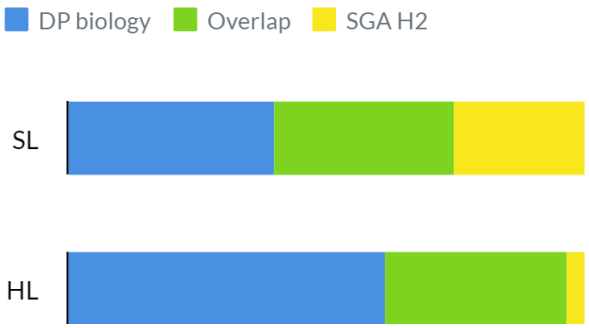
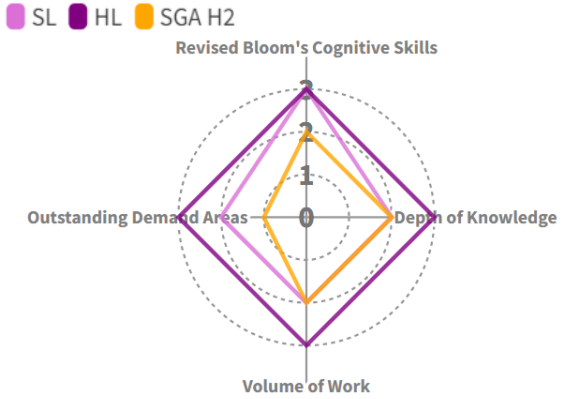
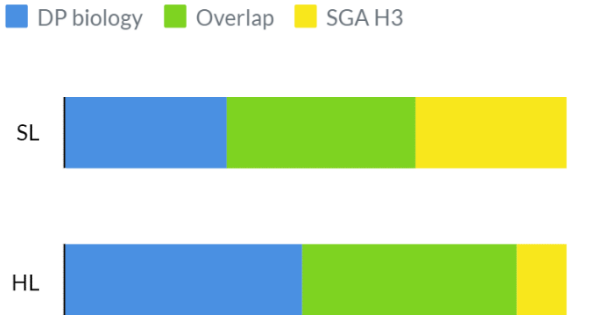
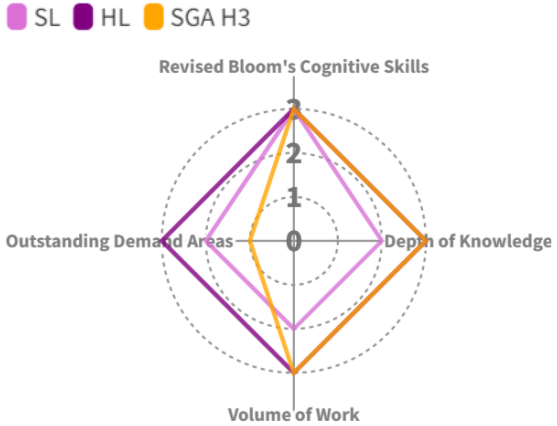
- **Differences in demand:** H1 is surpassed by DP SL and HL for all demand categories, hence has low alignment in terms of demand. H2 chemistry has a slightly lower score for the presence of higher order thinking skills and does not match the DP HL in any other categories. All three SGA chemistry subjects have fewer outstanding demand areas than the DP and therefore score consistently less in this category.

6.2.4 Biology Alignment

The subject level alignment between the DP biology and SGA biology is represented below:

Figure 30: Visual representations of subject-level alignment (biology)

Subject name	Learning outcomes alignment	Content alignment	Demand alignment
H1 biology			

Subject name	Learning outcomes alignment	Content alignment	Demand alignment
H2 biology	Low Moderate **High**		
H3 biology	Low Moderate **High**		

- **Learning outcomes alignment**: the level of alignment between the learning outcomes of DP and SGA biology is significant, with nearly all themes extracted from the DP learning outcomes being present in the SGA's learning outcomes.

- **Content alignment**: the alignment between SGA and DP biology content is generally moderate, due to the limited overlapping content between the two. The majority of SL and HL topics are not present in H1, which has less breadth and depth than both SL and HL. There is a moderate level of alignment with H2, and a slightly stronger alignment if H3 is also studied; however, there are still significant DP content areas that are not covered in the SGA syllabi, especially sub-topics from A. Unity and Diversity. Overall, of the different SGA routes available to students, H3 has the closest similarity to the DP regarding breadth and depth of content.

- **Demand alignment**: H1 is surpassed in all demand categories by both SL and HL, whereas H2 and H3 score similarly to DP SL and DP HL, respectively.

The **key similarities** identified were the following:

- **Similarities in learning outcomes:** each SGA biology subject available in Singapore covers most of the DP themes. Conceptual understanding, techniques that characterise science and an awareness of local and global problems are strongly emphasised within biology. Like the DP, the SGA also places importance on creativity and critical thinking and skills for scientific inquiry within their learning outcomes. The DP theme of communication and collaboration is also further emphasised in the general outcomes and those for H3 biology.

- **Similarities in content:** content from topic D – Continuity and change is consistently present across all SGA biology subjects, as is content from the SL sub-topics A.2 Cells, B.1 Molecules, B.2 Cells and C.1 Molecules. AHL content is present in H2 and H3 biology, particularly in the topics B – Form and function, C – Interactions and independence and D – Continuity and change. Furthermore, the SGA subjects have alignment with the DP's experimental programme, as practical work and scientific inquiry are features of all.

- **Similarities in demand:** the scores for the presence of higher order cognitive skills (taken from Bloom's Revised Taxonomy) are the same for the DP and H3 biology, as they place similar emphasis on analysis, evaluation, and creation in their learning outcomes. H2 biology also has the same scores as the DP SL content for depth of knowledge and volume of work, reflecting the similar breadth and depth of H2 biology and DP SL. As well as Bloom's, H3 has the same scores as DP HL in a further two categories: depth of knowledge and volume of work.

The **key differences** identified were the following:

- **Differences in learning outcomes:** the DP's theme of developing technology skills is not found within any area of the SGA biology outcomes.

- **Differences in content:** there are many areas of the DP SL and AHL content that are not found in the SGA H1 biology course. A significant portion of content from SL topics A – Unity and diversity and C – Interaction and independence is absent, and no alignment with AHL content is present, aside from two sub-topics (D.2 Cells and D.4 Ecosystems). H2 also does not include a significant amount of SL and AHL content, especially from A – Unity and diversity. Though H3 has more sub-topic alignments than H2 and H1, no biology subject is comparable to the DP HL in breadth and depth.

- **Differences in demand:** H1 biology has been given lower scores in all categories than the DP SL and AHL, as it has less breadth and depth and is less challenging. H2 biology has a lower Bloom's score than SL due to the more limited presence of higher order thinking skills and does not score similarly to DP HL in any other category. All three SGA biology subjects have fewer outstanding demand areas than the DP and, therefore, score consistently lower in this category.

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Appendix A

This Appendix provides further detail on the criteria utilised by Ecctis' experts and external panel members with subject expertise to measure demand for each of the subjects analysed in this study.

Demand Profile – Subject-level Judgement

- **Revised Bloom's cognitive** skills score (0-3): this is an overall score of course demand, based entirely on a review of learning outcomes. Levels have been defined based on increasing emphasis on Bloom's Higher Order Thinking Skills.

    - Level 0 – remembering and understanding: learning outcomes (as well as assessment and content) are primarily focused on recall and understanding, with limited or no evidence of higher order thinking skills.
    - Level 1 – applying: learning outcomes (as well as assessment and content) comprise a mix of recall-, understanding- and application-focused objectives, with only limited presence of higher order thinking skills.
    - Level 2 – analysing: learning outcomes (as well as assessment and content) comprise a mix of recall-, understanding and application-focused goals but also feature a substantial focus on analysis. Learning outcomes can also potentially feature some (though limited) evidence of evaluation and creation-focused goals.
    - Level 3 – evaluating and creating (or synthesising): learning outcomes (as well as assessment and content) feature a predominant focus on analysis-, evaluation- and creation/synthesis.

- **Depth of knowledge** (adapted from Webb's) score (0-3): this is an overall score evaluating the depth of knowledge or complexity of knowledge required by curriculum standards and expectations. The score is focused on subject content and learning outcomes, complemented by assessment where relevant/possible. Levels have been defined based on the level of detail studied per topic, as well as the levels of thinking described in Webb's Depth of Knowledge framework.

    - Level 0 – All or most topics are studied in limited detail (pre-upper secondary level). Only basic pre-requisite knowledge is required in order to grasp ideas. The level of cognitive complexity of the information students are expected to know is low (e.g. many tasks may require recall and reproduction of information such as facts, definitions, terms, or simpler procedures – acquired knowledge).
    - Level 1 – Some topics are studied in considerable detail. Moderate levels of pre-requisite knowledge are required in order to grasp ideas in some topics. The level of cognitive complexity of the information students are expected to know is low to moderate (e.g. many tasks may require engagement of some mental processing beyond habitual responses, including comparison and basic reasoning – knowledge application).

  - Level 2 – Most topics are studied in considerable detail. Considerable pre-requisite knowledge is required in order to grasp ideas in some topics. The level of cognitive complexity of the information students are expected to know is average to high (e.g. some tasks require complex reasoning, planning, using evidence, and a higher level of thinking than the previous two levels. The cognitive demands are often complex and abstract – analysis).
  - Level 3 – All or most topics are studied in very high detail. Considerable pre-requisite knowledge is required in order to grasp ideas in most topics. The level of cognitive complexity of information students are expected to know is mostly high (e.g. many tasks may require complex reasoning, planning, developing, information synthesis, interpretation of data for problem solving, and thinking most likely over an extended period – extended thinking).

- **Volume of work** score (0-3): this is a trifactor score, considering breadth of content and depth of content, evaluated against the programme's specified timeframe. The three factors – breadth, depth, and time – were all considered in defining the levels.

  - Level 0 – light: small number of themes and sub-themes covered; a significant majority of time is spent on straightforward or basic themes; generous time allocation per theme.
  - Level 1 – moderate: typical number of themes and sub-themes covered; more time spent on conceptually complex themes compared to Level 1 (though majority of time still spent on themes of basic depth); standard time allocation per theme.
  - Level 2 – moderate heavy: typical to high number of themes and sub-themes covered; a significant proportion of time spent on issues beyond basic conceptual depth; standard to short time allocation per theme.
  - Level 3 – heavy: high number of themes and sub-themes covered; a large proportion of time spent on issues beyond basic conceptual depth; short time allocation per theme.

- **Outstanding areas of subject demand** score (0-3): this score reflects the number of content areas typically viewed as more challenging and/or conducive to intellectual stretching of learners. Levels have been defined on a scale of increasing presence of 'stretch areas'.

  - Level 0 – no stretch areas (0)
  - Level 1 – few stretch areas (1-2)
  - Level 2 – a significant number of stretch areas (3-4)
  - Level 3 – a high number of stretch areas (>4)

Appendix B

Learner profile	Approaches to learning	Approaches to teaching	International-mindedness
Inquirers: We nurture our curiosity, developing skills for inquiry and research. We know how to learn independently and with others. We learn with enthusiasm and sustain our love of learning throughout life. **Knowledgeable**: We develop and use conceptual understanding, exploring knowledge across a range of disciplines. We engage with issues and ideas that have local and global significance. **Thinkers**: We use critical and creative thinking skills to analyse and take responsible action on complex problems. We exercise initiative in making reasoned, ethical decisions. **Communicators**: We express ourselves confidently and creatively in more than one language and in many ways. We collaborate effectively, listening carefully to the perspectives of other individuals and groups. **Principled**: We act with integrity and honesty, with a strong sense of fairness and justice, and with respect for the dignity and rights of people everywhere. We take responsibility for our actions and their consequences. **Open Minded**: We critically appreciate our own cultures and personal histories, as well as the values and traditions of others. We seek and evaluate a range of points of view, and we are willing to grow from the experience.	In all IB programmes, there are five categories of skills including: **Thinking skills:** including areas such as critical thinking, creative thinking, and ethical thinking **Research skills:** including skills such as comparing, contrasting, validating, and prioritizing information **Communication skills:** including skills such as written and oral communication, effective listening, and formulating arguments **Social skills:** including areas such as forming and maintaining positive relationships, listening	In all IB programmes, teaching is: **Based on inquiry:** A strong emphasis is placed on students finding their own information and constructing their own understandings. **Focused on conceptual understanding:** Concepts are explored in order to both deepen disciplinary understanding and to help students make connections and transfer learning to new contexts. **Developed in local and global contexts:** Teaching uses real-life contexts and examples, and students are encouraged to process new information by connecting it to their own experiences and to the world around them. **Focused on effective teamwork and collaboration:** This includes promoting teamwork and collaboration between students, but also refers to the collaborative relationship between teachers and students.	The aim of all IB programmes is to develop internationally minded people who recognize their common humanity and shared guardianship of the planet. Central to this aim is international-mindedness. International-mindedness is a multifaceted concept that captures a way of thinking, being and acting characterised by an openness to the world and a recognition of our deep interconnectedness to others. To be open to the world, we need to understand it. IB programmes therefore provide students with opportunities for sustained inquiry into a range of local and global issues and ideas. This willingness to see beyond immediate situations and boundaries is essential as globalization and emerging technologies continue to blur traditional distinctions between the local, national and international. An IB education fosters international-mindedness by helping students reflect on their own perspective, culture and identities, as well as those of others. By engaging with diverse beliefs, values and experiences, and by learning to think and collaborate across cultures and disciplines, IB learners gain the understanding necessary to make progress towards a more peaceful world.

Caring: We show empathy, compassion, and respect. We have a commitment to service, and we act to make a positive difference in the lives of others and in the world around us. **Risk-Takers**: We approach uncertainty with forethought and determination; we work independently and cooperatively to explore new ideas and innovative strategies. We are resourceful and resilient in the face of challenges and change. **Balanced**: We understand the importance of balancing different aspects of our lives – intellectual, physical, and emotional – to achieve well-being for ourselves and others. We recognize our interdependence with other people and with the world in which we live. **Reflective**: We thoughtfully consider the world and our own ideas and experience. We work to understand our strengths and weaknesses in order to support our learning and personal development.	skills, and conflict resolution **Self-management skills:** including both organizational skills, such as managing time and tasks, and affective skills, such as managing state of mind and motivation.	**Designed to remove barriers to learning:** Teaching is inclusive and values diversity. It affirms students' identities, and aims to create learning opportunities that enable every student to develop and pursue appropriate personal goals. **Informed by assessment:** Assessment plays a crucial role in supporting, as well as measuring, learning. This approach also recognizes the crucial role of providing students with effective feedback.	An IB education further enhances the development of international-mindedness through multilingualism. All IB programmes require students to study, or study in, more than one language. This is because we believe that communicating in more than one language helps students to appreciate that his or her own language, culture and world view are just one of many. In this way, it provides excellent opportunities to develop intercultural understanding and respect. International-mindedness is also encouraged through a focus on global engagement and meaningful service with the community. These elements challenge students to critically consider power and privilege, and to recognize that they hold this planet and its resources in trust for future generations. They also highlight the focus on action in all IB programmes: a focus on moving beyond awareness and understanding to engagement, action and bringing about meaningful change to make a more peaceful and sustainable world for everyone.

Appendix C

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Task brief – Expert Demand Panel – [Subject]

For each subject, highlight in yellow the descriptor(s) deemed to best fit each demand category, using the following criteria (please refer to the demand tables for descriptors of the levels):

- **Revised Bloom's cognitive skills** score (0-3): this is an overall score of course demand, based entirely on a review of learning outcomes. Levels have been defined based on increasing emphasis on Bloom's Higher Order Thinking Skills.

- **Depth of knowledge** (adapted from Webb's) score (0-3): this is an overall score evaluating the depth of knowledge or complexity of knowledge required by curriculum standards and expectations. The score is focused on subject content and learning outcomes, complemented by assessment where relevant/possible. Levels have been defined based on the level of detail studied per topic, as well as the levels of thinking described in Webb's Depth of Knowledge framework.

- **Volume of work** score (0-3): this is a trifactor score, considering breadth of content and depth of content, evaluated against the programme's specified timeframe. The three factors – breadth, depth and time – were all taken into account in defining the levels.

- **Outstanding areas of subject demand** score (0-3): this score reflects the number of content areas typically viewed as more challenging and/or conducive to intellectual stretching of learners. Levels have been defined on a scale of increasing presence of 'stretch areas'.

Demand Judgements – [Subject]

Table 25: [Subject]

Demand Judgement	Score Descriptors (highlight the best-fit descriptor)	Judgement and Key Evidence
Revised Bloom's Cognitive Skills[137]	Level 0 – remembering and understanding: learning outcomes are primarily focused on recall and understanding, with limited or no evidence of higher order thinking skills.	
	Level 1 – applying: learning outcomes (as well as assessment and content) comprise a mix of recall-, understanding- and application-focused objectives, with only limited presence of higher order thinking skills.	
	Level 2 – analysing: learning outcomes (as well as assessment and content) comprise a mix of recall-, understanding and application-focused goals but also feature a substantial focus on analysis. Learning outcomes can also potentially feature some (though limited) evidence of evaluation and creation-focused goals.	
	Level 3 – evaluating and creating (or synthesising): learning outcomes feature a predominant focus on analysis-, evaluation- and creation/synthesis.	
Depth of Knowledge[138]	Level 0 – All or most topics are studied in limited detail (pre-upper secondary level). Only basic pre-requisite knowledge is required in order to grasp ideas. The level of cognitive complexity of the information students are expected to know is low (e.g. many tasks may require recall and reproduction of information such as facts, definitions, terms, or simpler procedures – acquired knowledge).	
	Level 1 – Some topics are studied in considerable detail. Moderate levels of pre-requisite knowledge are required in order to grasp ideas in some topics. The level of cognitive complexity of the information students are expected to know is low to moderate (e.g. many tasks may require engagement of some mental processing beyond habitual responses, including comparison and basic reasoning – knowledge application).	
	Level 2 – Most topics are studied in considerable detail. Considerable pre-requisite knowledge is required in order to grasp ideas in some topics. The level of cognitive complexity of the information students are expected to know is average to high (e.g. some tasks require complex reasoning, planning, using evidence, and a higher level of thinking than the previous two	

[137] Evidence pool: Learning outcomes
[138] Evidence pool: Learning outcomes, subject content, assessment types

Demand Judgement	Score Descriptors (highlight the best-fit descriptor)	Judgement and Key Evidence
	levels. The cognitive demands are often complex and abstract – analysis).	
	Level 3 – All or most topics are studied in very high detail. Considerable pre-requisite knowledge is required in order to grasp ideas in most topics. The level of cognitive complexity of information students are expected to know is mostly high (e.g. many tasks may require complex reasoning, planning, developing, information synthesis, interpretation of data for problem solving, and thinking most likely over an extended period of time – extended thinking).	
Volume of work[139]	Level 0 – light: small number of themes and sub-themes covered; a significant majority of time is spent on straightforward or basic themes; generous time allocation per theme.	
	Level 1 – moderate: typical number of themes and sub-themes covered; more time spent on conceptually complex themes compared to Level 1 (though majority of time still spent on themes of basic depth); standard time allocation per theme.	
	Level 2 – moderate heavy: typical to high number of themes and sub-themes covered; a significant proportion of time spent on issues beyond basic conceptual depth; standard to short time allocation per theme.	
	Level 3 – heavy: high number of themes and sub-themes covered; a large proportion of time spent on issues beyond basic conceptual depth; short time allocation per theme.	
Outstanding areas of subject demand[140]	Level 0 – no stretch areas (0)	
	Level 1 – few stretch areas (1-2)	
	Level 2 – a significant number of stretch areas (3-4)	
	Level 3 – a high number of stretch areas (>4)	

[139] Evidence pool: Subject content; assessment types and number; course duration; time allocated per topic/sub-topic (where available).
[140] Evidence pool: Subject content.