DP Country Alignment Studies: Alignment of DP Biology with the Biology Subjects in Eleven Comparison Programmes/Standards

Submitted to the IB by Ecctis

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Acronyms

21CC	21st century competencies
AHL	Additional Higher Level
BGE	Basic General Education
BHSC	Brazilian High School Curriculum
BNCC	(Brazilian) National Common Curricular Base
CAS	creativity, activity, service
CCSS	Common Core State Standards
CP	Career-related Programme
DP	Diploma Programme
EDUFI	Finnish National Agency for Education
FB	French Baccalaureate (*Baccalauréat)*
FI	Formative Itinerary
FNCC	Finnish National Core Curriculum
GCE	General Certificate of Education
GUSE	General upper secondary education
HL	Higher Level
HS	High School
IB	International Baccalaureate
IBO	International Baccalaureate Organisation
JHSC	Japanese High School Curriculum
KHSCG	South Korean High School Certificate of Graduation
LS	Life Sciences
MAT	Mathematics and Technology
MBG	Mexican Bachillerato General
MEXT	Ministry of Education, Culture, Sports, Science and Technology
MOE	Ministry of Education

MT	Mathematical Thinking
MYP	Middle Years Programme
NGSS	Next Generation Science Standards
OSSD	Ontario Secondary School Diploma
OSSLT	Ontario Secondary School Literacy Test
PoS	Practices of Science
PS	Physical Sciences
PYP	Primary Years Programme
RfP	Request for Proposal
RQ	Research Question
SGA	Singaporean GCE A Level
SL	Standard Level
SMC	Science and Mathematics Course
TOK	Theory of Knowledge
UP	University Preparation
USA	United States of America
VCAA	Victorian Curriculum and Assessment Authority
VCE	Victorian Certificate of Education

Contents

1. Executive Summary

1.1 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 conduct a series of in-depth studies that assessed the level of alignment between the DP and comparison points within the upper secondary education systems of Australia (Victoria), Canada (Ontario), the United States, Singapore, South Korea, Finland, France, Spain, Brazil, Mexico, and Japan.[1] The studies identified areas of similarity and difference between the DP and these educational systems, providing valuable insights to inform the IB's development of tools and resources for IB teachers, supporting their navigation between the DP and local curriculum of each country. The studies also contributed to supporting fair recognition of the DP by institutions, employers, and other key stakeholders – ultimately supporting the progression and mobility of DP graduates. For all countries, the studies assessed alignment at both the programme and subject levels, with a particular focus on mathematics and science. For some countries, additional subjects were included in the analysis, as outlined in the table below:

Table I: Additional subjects included in the country studies.

Country	Additional DP Subject(s)	Country	Additional DP Subject(s)
Australia	History	Brazil	Language A: language and literature History Philosophy Brazilian social studies
United States	English		
France	Philosophy Theory of knowledge (TOK)		
		Mexico	Language A: language and literature
Spain	Economics Business management	Japan	Language A: literature Language B History

This report constitutes one of the project's deliverables and aims to specifically answer the research questions pertaining to how DP biology aligns with the biology curriculum in each of the comparison programmes/standards in these studies, namely:

- Australia: Victorian Certificate of Education (VCE)
- Canada: Ontario Secondary School Diploma (OSSD)
- Finland: Finnish National Core Curriculum (FNCC)/General Upper Secondary Education (GUSE)
- Singapore: Singaporean GCE A Level (SGA)
- South Korea: Korean High School Certificate of Graduation (KHSCG)
- US: Next Generation Science Standards (NGSS)
- France: French Baccalauréat (FB)

[1] The IB DP Country Alignment reports can be accessed at: www.ibo.org/research/curriculum-research/dp-studies/dp-country-alignment-studies-2023/

- Spain: Spanish Bachillerato (SB)
- Brazil: Brazilian High School Curriculum (BHSC)
- Mexico: Mexican Bachillerato General (MBG)
- Japan: Japanese High School Curriculum (JHSC).

1.2 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 do the DP biology curricula align with the upper secondary biology curricula of the eleven comparison programmes? In what way are the curricula similar and in what way are they different? To what degree do the subjects align with regard to:
1.1: Content
- Topics (i.e. scope of content area, breadth, depth)
- Learning activities (i.e. difficulty, demand).

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

To answer the above RQs, Ecctis developed and applied a bespoke methodology which involved the comparative analysis of key components of the DP and the comparison 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.[2]

[2] 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).

1.3 Key Findings

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

Table II: DP and comparison subjects.

		Comparison subjects per country and comparison programme					
Country	**International**	**Australia**	**Canada**	**Finland**	**Singapore**	**South Korea**	**US**
Programme/ Standards	**DP**	**Victoria (VCE)**	**Ontario (OSSD)**	**Finland (FNCC)**	**Singapore (SGA)**	**South Korea (KHSCG)**	**Next Generation Science Standards (NGSS)**
Subjects	Biology SL and HL	Biology Units 1, 2, 3 & 4	Grade 9 & 10 Science: Academic Grade 11 & 12 Biology	Biology	Higher 1 (H1) Biology Higher 2 (H2) Biology Higher 3 (H3) Biology	Biology I Biology II Integrated Science Scientific Investigation	Life Sciences standards (high school)
		Comparison subjects per country and comparison programme (continued)					
		France	**Spain**	**Brazil**	**Mexico**	**Japan**	
		France (FB)	**Spain (SB)**	**Brazil (BHSC)**	**Mexico (MBG)**	**Japan (JHSC)**	
		Life and Earth Sciences	Biology, Geology and Environmental Sciences Biology	Natural Sciences and Technology (Basic General Education and Formative Itinerary)	Natural Sciences, Experimental Sciences and Technology units	Advanced Biology Biology for the Science and Mathematics Course	

Detailed findings from the subject-level analysis are summarised in the 5. Key Findings section and fully detailed in the respective country sections in the main body of this report:

- Australia: Victorian Certificate of Education (VCE)
- Canada: Ontario Secondary School Diploma (OSSD)
- Finland: Finnish National Core Curriculum (FNCC) / General Upper Secondary Education (GUSE)
- Singapore: Singaporean GCE A Level (SGA)
- South Korea: Korean High School Certificate of Graduation (KHSCG)
- USA: Next Generation Science Standards (NGSS).
- France: French Baccalauréat
- Spain: Spanish Bachillerato
- Brazil: Brazilian High School Curriculum (BHSC)
- Mexico: Mexican Bachillerato General (MBG)
- Japan: Japanese High School Curriculum (JHSC)

1.4 Cross-cutting Findings

In addition to the insights gained from the analysis of each comparison subject against DP chemistry, the study also adopted a cross-cutting perspective of the chemistry curricula across all countries included in the studies. This horizontal analysis identified key similarities, differences, and trends relating to learning outcomes, content and demand. The findings are summarised in the visuals and bullet points that follow.

1.4.1 Learning Outcomes

Table III: Presence of the DP's science learning outcome themes in the comparison curricula

Themes extracted from learning outcomes of the DP sciences subject group	Presence in the comparison curricula										
	VCE (Victoria)	OSSD (Ontario)	FNCC/ GUSE (Finland)	SGA (Singapore)	KHSCG (South Korea)	NGSS (US)	FB (France)	SB (Spain)	BHSC (Brazil)	MBG (Mexico)	JHSC (Japan)
1. Conceptual understanding and making connections											
2. Use and application of knowledge, methods, tools, and techniques that characterize science											
3. Creativity and critical thinking (problem-solving, analysis, evaluation, synthesis)											
4. Skills for scientific inquiry											
5. Development of technological skills											
6. Effective collaboration and communication											
7. Awareness of global and local problems and the environmental, ethical, cultural, and social impact of science											

Key:

	This theme is well-evidenced in the learning outcomes of the comparison curriculum.
	This theme is partially evidenced in the learning outcomes of the comparison curriculum.
	This theme is not evidenced in the learning outcomes of the comparison curriculum.

The table above displays the learning outcome themes extracted from the DP sciences subject group (which apply to biology) and summarises their presence in the biology curricula of the eleven comparison programmes/standards.

- Overall, most comparison biology curricula have a high degree of alignment with the DP's learning outcomes for science. Rarely are the DP's learning outcome themes absent from the comparison curricula and, from the other perspective, very few themes emerge from the comparison curricula that are significantly different to the DP's. Alignment is particularly strong between the learning outcomes in the DP and those in the VCE, OSSD, FNCC, KHSCG, and MBG.

- In contrast to the DP, FB and NGSS, the other curricula have course-specific outcomes, with some featuring both overarching outcomes for the sciences subject area and course-specific outcomes. That said, the course-specific outcomes for OSSD, VCE, FNCC, KHSCG, and JHSC differ primarily because they are contextualised for the content of each course; whereas the SGA, SB, BHSC, and MBG contain outcomes which describe somewhat different skills for each course, as well as content.

- The DP's themes of *Using and applying knowledge, methods, tools, and techniques that characterise science*, *Creativity and critical thinking*, and *Skills for scientific inquiry* have the strongest presence across the learning outcomes of the curricula. Other themes are generally well represented but may be partially present, or not evidenced, in a few curricula.

- There are a few different learning outcomes themes or focuses in the comparison curricula. The OSSD and FNCC learning outcomes have a stronger national focus. In addition, the OSSD's significant emphasis on careers and the FNCC's emphasis on collaboration with outside agencies as a means to gaining skills and knowledge in biology are also less predominant in the DP biology's outcomes; as is NGSS's focus on using models and computational thinking. The BHSC's learning outcomes include a focus on historical scientific discoveries and a larger emphasis on engaging with scientific literature.

1.4.2 Content

Table IV: Presence of DP biology SL content in the biology curricula of the comparison programmes/standards.[3]

DP biology themes and levels (SL content)		Presence in comparison curricula										
		VCE	OSSD	FNCC	SGA	KHSCG	NGSS	FB	SB	BHSC	MBG	JHSC
A. Unity and diversity	1. Molecules											
	2. Cells											
	3. Organisms											
	4. Ecosystems											
B. Form and function	1. Molecules											
	2. Cells											
	3. Organisms											
	4. Ecosystems											
C. Interaction and interdependence	1. Molecules											
	2. Cells											
	3. Organisms											
	4. Ecosystems											
D. Continuity and change	1. Molecules											
	2. Cells											
	3. Organisms											
	4. Ecosystems											
Experimental programme												

Key:

	Strong presence of this level in the comparison curriculum.		*Partial presence of this level in the comparison curriculum.*		*Little or no presence of this level in the comparison curriculum.*

[3] NB: only topics covered featured at the respective level (i.e. SL) have been included in the table.

Table V: Presence of DP biology AHL content in the biology curricula of the comparison programmes/standards.[4]

DP biology themes and levels (AHL content)		Presence in comparison curricula										
		VCE	OSSD	FNCC	SGA	KHSCG	NGSS	FB	SB	BHSC	MBG	JHSC
A. Unity and diversity	1. Molecules											
	2. Cells											
	3. Organisms											
	4. Ecosystems											
B. Form and function	1. Molecules											
	2. Cells											
	3. Organisms											
C. Interaction and interdependence	1. Molecules											
	2. Cells											
	3. Organisms											
D. Continuity and change	1. Molecules											
	2. Cells											
	3. Organisms											
	4. Ecosystems											
Experimental programme												

Key:

	Strong presence of this level in the comparison curriculum.		*Partial presence of this level in the comparison curriculum.*		*Little or no presence of this level in the comparison curriculum.*

The tables above summarise the presence of DP biology SL and AHL content in the biology curricula of the eleven comparison programmes/standards. All biology content in the curriculum of each programme/standards is considered here. To view the biology content within specific subjects, and how it aligns with DP biology, refer to the relevant country in Section 4. Subject-Level Alignment of the report.

[4] NB: only topics covered featured at the respective level (i.e. AHL) have been included in the table.

1.4.2.1 Structure

- Some curricula differ to the DP (and other curricula) by combining biology with other sciences in some of their subjects/units. The combining of biology with other sciences is a particular feature of the FB, SB, BHSC, and MBG. Indeed, the BHSC's formative itinerary component combines physics, chemistry and biology, as do the MBG's core units. The FB and SB combine biology with earth sciences in all or some of their courses.

- Like most comparison biology subjects, the DP breaks its biology content down into a small number of overarching areas, with each being further divided into levels and then topics. Other curricula organise content into areas and topics, with the exact number of topics varying. However, DP biology is unique in its organisation of content into themes and levels.

- Somewhat uniquely, DP biology's content structure stays the same for both SL and HL. The SGA takes a similar approach, featuring the same five overarching topic areas in both H1 and H2, though the latter includes an additional extension topic not featured in the former. In contrast, in the remaining comparison curricula, different biology courses within the same programme have different overarching topics and thematic focuses.

- In the DP and most comparison curricula, all content within a specific biology course is compulsory. The few exceptions to these are the FNCC and VCE, which feature optional topics and areas.

1.4.2.2 Content Alignment

- Some content from each of the DP's four main themes of *A. Unity and diversity*, *B. Form and function*, *C. Interaction and interdependence*, and *D. Continuity and change* is found in most comparison curricula. This is generally true for both SL content and AHL content, except for the NGSS, BHSC, MBG, and JHSC. The NGSS features no significant AHL content from themes B and C, the BHSC does not include any AHL content, the MBG does not contain any AHL content from themes B and D, and the JHSC contains no significant SL or AHL content from theme B.

- DP biology SL content is generally well-covered by most comparison curricula. The exceptions to this are the FNCC, BHSC, MBG, and JHSC. Coverage of SL content in *B. Form and function* and *D. Continuity and change* is particularly low in the MBG and JHSC.

- With regards to DP biology AHL content, most comparison curricula cover at least some content from each of the DP's four main themes, with the exception of the NGSS, BHSC, MBG, and JHSC. However, across the curricula, this coverage of AHL content is less comprehensive than that of the SL content, with considerably more instances of no alignment or partial alignment found. The AHL content from *A1. Molecules*, *A4. Ecosystems*, and *C3. Organisms* is the least present across the curricula.

- When considering large topics or content areas which are present in the comparison curricula but not in the DP, this was mostly observed in the FNCC, SGA, KHSCG, SB, BHSC, MBG, and JHSC, with each containing topics which are not found in the DP. Most commonly, the content absent from the DP relates to aspects of biotechnology and its importance.

- Overall, as can be seen in the tables, the OSSD, KHSC, FB, and SB have the strongest content alignment with DP biology, as each includes a significant amount of SL and AHL content.

1.4.3 Demand

The following table provides a visual representation of the demand scores the expert panel awarded to the DP biology and respective comparison subjects in each of the eleven comparison programmes/standards.

Table VI: The demand scores of biology subjects from the DP and eleven comparison programmes

Demand category	Scores																		
	DP (IB)		VCE	OSSD		FNCC		SGA			KHSCG	NGSS	FB	SB	BHSC		MBG		JHSC	
	SL	HL	Bio.	G. 11	G. 12	C	All	H1	H2	H3	Biology	LS	LES	Bio.	BGE	FI	C	All	AB	S
Revised Bloom's Cognitive Skills	3	3	2.5	2	2.5	2	3	2	2	3	2	2	2	2.5	2.5	3	2	2	2	2
Depth of Knowledge	2	3	2	1.5	2	1.5	2	1	2	3	2	1	2	2	1	2	1	1.5	1.5	2
Volume of Work	2	3	1	2	2	1.5	2	1	2	3	2	0	2	2.5	0.5	1.5	0	1	1	1.5
Outstanding Demand Areas	2	3	0	0	1	1	1	0	1	1	1	0	1	2	1	2	1	1	1	1

Key:

VCE (Australia): Bio: Biology	**OSSD (Canada):** G.11: Grade 11 Biology G.12: Grade 12 Biology	**FNCC/GUSE (Finland):** C: Compulsory Biology modules All: Compulsory and optional Biology modules	**SGA (Singapore):** H1: Higher 1 Biology H2: Higher 2 Biology H3: Higher 3 Biology	**KHSCG (South Korea):** Biology: Biology I, Biology II, Integrated Science, and Scientific Investigation combined	**NGSS (US):** LS: Standards for Life Sciences
FB (France): LES: Life and Earth Sciences	**SB (Spain):** Bio: Biology	**BHSC (Brazil)** BGE: Basic general education FI: Formative itinerary	**MBG (Mexico):** C: Compulsory science units (biology) All: Compulsory and optional science units (biology)	**JHSC (Japan):** AC: Advanced Biology S: Biology for the Science and Mathematics Course	

- Only a few curricula contain a subject which scores the same as DP biology for Bloom's cognitive skills (which obtained a score of 3 for this category). The lower scores in the rest of the curricula reflect a more limited presence of evaluation and creativity in their learning outcomes. However, it is worth noting that the difference in scores is often small, with the VCE, OSSD, SB, and BHSC having a subject which scores 2.5. None of the subjects/pathways examined score less than a 2, showing that analysis and some higher order thinking is present in the subjects of all curricula.

- As can be seen in the figure above, most comparison curricula have at least one subject/pathway which scores the same as DP biology SL for depth of knowledge. The NGSS and MBG subjects score lower – partially because the lack of detail in the NGSS standards' documentation makes it difficult to ascertain their true depth. Only the SGA has a course that scores the same as DP biology HL for depth of knowledge (i.e. the maximum score for this category). Lastly, the NGSS, OSSD, SGA, FNCC, BHSC, MBG, and JHSC all have one subject/pathway which scores less than DP biology SL in this category.

- Regarding volume of work, a number of comparison curricula have courses that score the same as DP biology SL for this category – namely the OSSD, KHSCG, FNCC, FB and SGA. The SGA and SB have courses which score greater than SL, with SGA H3 scoring the same as DP biology HL for volume of work. Notably, a number of comparison programmes/standards offer subjects with a lower volume of work than both SL and HL, namely the VCE, FNCC, SGA, NGSS, BHSC, MBG, and JHSC

- All comparison curricula, except one, score lower than the DP in the category of outstanding areas of subject demand, compared to both SL and HL. Only the SB and BHSC have courses which score the same as DP biology SL.

- In summary, whilst most comparison programmes/standards offer a biology subject that has good alignment with DP biology SL, only the SGA and SB offer a subject that has reasonable alignment with DP biology HL. Furthermore, outstanding areas of demand is the primary category in which comparison subjects score lower than the DP, with both SL and HL featuring a higher number of outstanding areas of subject demand than most.

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'.[5]

Ecctis was commissioned by the IB to conduct 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 (Victoria), Canada (Ontario), the United States, Singapore, South Korea, Finland, France, Spain, Brazil, Mexico, and Japan.[6] More specifically, the studies identified areas of similarity and difference between the DP and these educational systems at the programme level by comparing philosophical underpinnings, structures, entry requirements, assessment methods, and learning pathways. The studies also examined how the DP compared with selected benchmarks in terms of intended student learning outcomes at the subject level. For all countries, the studies focused on mathematics and sciences, with some also including additional subjects, as outlined in the table below:

Table 1: Additional subjects included in the country studies

Country	Additional DP Subject(s)	Country	Additional DP Subject(s)
Australia	History	Brazil	Language A: language and literature History Philosophy Brazilian social studies (BSS)
United States	English		
France	Philosophy Theory of knowledge (TOK)		
		Mexico	Language A: language and literature
Spain	Economics Business management	Japan	Language A: literature Language B History

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

This report forms one of the key deliverables of the project and is designed to address the research questions related to the extent of alignment between DP biology and the biology subjects within each of the eleven comparison programmes/standards examined in these studies, namely:

[5] International Baccalaureate. (2022). *Diploma Programme*. Available from: https://www.ibo.org/programmes/diploma-programme/

[6] The full reports can be accessed at: www.ibo.org/research/curriculum-research/dp-studies/dp-country-alignment-studies-2023/

- Australia: Victorian Certificate of Education (VCE)
- Canada: Ontario Secondary School Diploma (OSSD)
- Finland: Finnish National Core Curriculum (FNCC)/General Upper Secondary Education (GUSE)
- Singapore: Singaporean GCE A Level (SGA)
- South Korea: Korean High School Certificate of Graduation (KHSCG)
- US: Common Core State Standards (CCSS)
- France: French Baccalauréat (FB)
- Spain: Spanish Bachillerato (SB)
- Brazil: Brazilian High School Curriculum (BHSC)
- Mexico: Mexican Bachillerato General (MBG)
- Japan: Japanese High School Curriculum (JHSC).

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 RQ is as follows:

Table 2: Research questions

RQ1: To what degree do the DP biology curricula align with the upper secondary biology curricula of the eleven comparison programmes? In what way are the curricula similar and in what way are they different? To what degree do the subjects align with regard to: 1.1: Content • Topics (i.e. scope of content area, breadth, depth) • Learning activities (i.e. difficulty, demand). 1.2: 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 3: DP biology subjects and comparison subjects

		Comparison subjects per country and comparison programme					
Country	**International**	**Australia**	**Canada**	**Finland**	**Singapore**	**South Korea**	**US**
Programme/ Standards	**DP**	**Victoria (VCE)**	**Ontario (OSSD)**	**Finland (FNCC)**	**Singapore (SGA)**	**South Korea (KHSCG)**	**Next Generation Science Standards (NGSS)**
Subjects	Biology SL and HL	Biology Units 1, 2, 3 & 4	Grade 9 & 10 Science: Academic Grade 11 & 12 Biology	Biology	Higher 1 (H1) Biology Higher 2 (H2) Biology Higher 3 (H3) Biology	Biology I Biology II Integrated Science and Scientific Investigation (common courses)	Life Sciences standards (high school) (NGSS life sciences)
		Comparison subjects per country and comparison programme (continued)					
		France	**Spain**	**Brazil**	**Mexico**	**Japan**	
		France (FB)	**Spain (SB)**	**Brazil (BHSC)**	**Mexico (MBG)**	**Japan (JHSC)**	
		Life and Earth Sciences	Biology, Geology and Environmental Sciences Biology	Natural Sciences and Technology (Basic General Education and Formative Itinerary)	Natural Sciences, Experimental Sciences and Technology units	Advanced Biology Biology for the Science and Mathematics Course	

2.3 Report Structure

In responding to the above RQ, this report includes 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 subject level; and an outline of the methodology used to assess demand.

- 4. Subject-Level Alignment: this section presents the synthesised analysis from the subject-level comparisons between the DP biology subjects and the biology subjects in the eleven comparison programmes. For each comparison subject, this includes the comparative analysis on their learning outcomes, content, and demand.

- 5. Key Findings: this section outlines the key findings from the subject-level comparisons undertaken between the DP biology subjects and those of each of the eleven comparison programmes. In doing so, it provides a top-level conclusion on subject-level alignment for each programme, and a succinct summary of key similarities and key differences.

- 6. Cross-cutting findings: this section outlines the key cross-cutting findings from the various subject-level comparisons carried out between the DP biology subjects and those of each of the eleven comparison programmes. In doing so, it unpicks the main trends identified at the learning outcomes, content and demand levels, highlighting noticeable similarities and 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 the comparative analyses at subject level, the following core documentation was reviewed (supplemented by additional documentation – detailed in the Bibliography – where relevant and available):

IB Documentation

- DP: From principles into practice
- Programme standards and practices
- DP biology subject guide.

Victoria Documentation

- Documentation by the Victorian Curriculum and Assessment Authority (VCAA), including information about underpinning philosophy and pedagogy
- VCE Biology Study Design.

Ontario Documentation

- Ontario Curriculum and Resources (website)
- The Ontario Curriculum – secondary subjects guides:
    - science (grades 9 and 10)
    - biology (grades 11 and 12).

Finland Documentation

- Finnish National Agency for Education – National Core Curriculum for General Upper
    - General Upper Secondary Subject Syllabus: Biology.

Singapore Documentation

- Ministry of Education (MOE) – Singapore (website)
- MOE – Singapore's Post-Secondary Education booklet
- The Singapore Curriculum – Pre-University Subject Syllabuses:
    - H1 biology
    - H2 biology
    - H3 biology.

South Korea Documentation

- MOE – The National Curriculum for Primary and Secondary Schools
- MOE – Education in Korea (website)
- MOE – Science Curriculum, including the biology electives.

NGSS Documentation

- The 'Principles of the Framework' section in the NGSS website.
- The NGSS for Life Sciences (high school).

France Documentation

- French Baccalaureate curriculum (website), including information about underpinning philosophy and pedagogy
- The French Baccalaureate – subject programmes:
    - Life and Earth Science *Général Première*
    - Life and Earth Science *Général Terminale.*

Spain Documentation

- Government of Spain, Ministry of Education and Vocational Training (website), including information about Key Competences of the SB,[7] as well as the specific competences (SCs), evaluation criteria and content covered in each of the following subjects:
    - biology, geology and environmental sciences
    - biology
- Where possible, due to the less detailed nature of the SB curriculum, this was complemented by a review of publicly available official textbooks. References to these can be found in the Bibliography section of this report.

Brazil Documentation

- Ministry of Education updates to the National Curriculum Guidelines for High School Education
- National Common Curricular Base (BNCC) for high school Natural Sciences and Technology
- Curricular References for the Preparation of Formative Itineraries
- Rio de Janeiro Referential Curriculum (RJRC)
- Rio de Janeiro specialisation pathways for formative itineraries in Natural Sciences and Technology.

Mexico Documentation

- Learning Progressions for Natural Sciences, Experimental Sciences and Technology
- Programmes of Study (Science):
    - Chemical Reactions – Conservation of Matter in the Formation of New Substances
    - Conservation of Energy and its Interaction with Matter
    - Ecosystems – Interactions, Energy and Dynamics
    - Energy in the Processes of Daily Life
    - Matter and its Interactions
    - Organisms, Structures and Processes. Heredity and Biological Evolution
    - Selected Topics in Biology I & II.

Japan Documentation

- High School Course of Study (Announced in 2018)
- Commentary on the High School Curriculum Guidelines for Science.

[7] Government of Spain, Ministry of Education and Vocational Training. (2022) Royal Decree 243/2022. https://www.boe.es/buscar/act.php?id=BOE-A-2015-37; https://educagob-educacionyfp-gob-es.translate.goog/curriculo/curriculo-lomloe/menu-curriculos-basicos/bachillerato/competencias-clave.html?_x_tr_sl=es&_x_tr_tl=en&_x_tr_hl=en-US&_x_tr_pto=wapp

3.1.1 Learning Outcomes Comparison

For the Learning Outcomes comparisons, as not all subjects in each of the qualifications reviewed explicitly name learning outcomes in their syllabi, Ecctis used the following categories of the curriculum documentation for comparison:

Table 4: Learning outcomes for comparison of the DP biology and respective comparison subjects

BIOLOGY		
Programme/ Standards	**Subject**	**Categories utilised as learning outcomes**
DP	biology	DP biology – aims and assessment objectives
Australia, Victoria (VCE)	Biology	Outcomes
Canada, Ontario (OSSD)	Biology	Overall Expectations
Finland (FNCC)	biology	task of the subject transversal competences general objectives
Singapore (SGA)	Biology H1, H2, H3	Practices of Science, Syllabus Aims
South Korea (KHSCG)	Biology I, Biology II, integrated science, scientific investigation	subject introductions (titled 'Character') objectives
USA (NGSS)	Life Sciences standards (high school) (NGSS life sciences)	High school Life Sciences standards • HS-LS1 From Molecules to organisms: Structures and Processes • HS-LS2 Ecosystems: Interactions, Energy, and Dynamics • HS-LS3 Heredity: Inheritance and Variation of Traits • HS-LS4 Biological Evolution: Unity and Diversity
France (FB)	Life and Earth Sciences	Skills developed as part of scientific research
Spain (SB)	Biology, Geology and Environmental Science Biology	Specific Competencies
Brazil (BHSC)	Natural Sciences and Technology (Basic General Education and Formative Itinerary)	Specific competencies and skills in the BNCC Skills in the curricular references for formative itineraries.
Mexico (MBG)	Natural Sciences, Experimental Sciences and Technology units	Learning Progressions Extended Disciplinary Competencies Generic Competencies
Japan (JHSC)	Basic Biology Advanced Biology	General Subjects - Science - subject area objectives and individual subject objectives
	Biology for the Science and Mathematics Course (SMC)	Specialised Subjects - Science and Mathematics – subject area objectives and individual subject objectives

Although not all 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.

3.1.2 Content Comparison

For the BHSC Natural Sciences and Technology (NST) subjects, it can be noted that the analysis drew upon a range of sources to establish a more detailed picture of the biology content used in high school education. The primary document used for basic general education (BGE) subjects is the BNCC (National Common Curricular Base). The BNCC merges skills and content into 'specific skills' for Natural Sciences and Technology. The specific skills emphasise skills rather than describing content through topics and subtopics and are generic to all sciences. As such, to provide a more concrete picture of the biology content covered, the Rio de Janeiro Referential Curriculum (RJRC) for high school was used to complement the BNCC for the content analysis of biology in BGE.

The RJRC was also used to analyse the content of a formative itinerary (FI) specialising in Natural Sciences and Technology. While the formative itineraries offered can vary from state to state, the RJRC provided insight into the type of biology content that these can cover. The analysis reviewed the specialisation pathways offered in Rio de Janeiro for a formative itinerary in Natural Sciences and Technology.[8]

The following table shows the documentation and sections that were used to inform the content analysis of each BHSC Natural Sciences and Technology (NST) subject.

Table 5: Documentation and sections used for the content analysis of BHSC subjects.

	Document: BNCC	Document: Curricular references for FI	Document: RJRC
BHSC subjects	Section	Section	Section
BHSC NST (BGE)	Specific competencies and skills for NST	N/A	Biology (for BGE)
BHSC NST (FI)	N/A	Specific skills associated with structuring axis	NST Specialisation Pathways (for the FI)

3.2 Measuring Alignment (Similarities and Differences)

Alignment is a key concept for this series of studies, which aims to unpick the level of alignment between the DP and each of the eleven comparison programmes. 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 eleven comparison programmes). 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.

[8] Formative itineraries which integrated several areas of knowledge were not reviewed.

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 have been considered within the subject reports. Namely:

- 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:

- Analysing to what extent each comparison programme has similarities with the DP.
- Analysing to what extent each comparison programme lacks features contained within the DP.
- Analysing to what extent the DP lacks features contained within each comparison programme.

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 subject and 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.

3.2.1 Mapping

To accurately measure the alignment of the DP subjects to each comparison programme's subjects, it was 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 comparison programmes 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.

Section 3.3 below provides further detail on how mapping has been applied in this study at subject level. For more information on how mapping has been applied in this series of studies at programme level, refer to sections 3.2.1 of the country alignment reports.

3.3 Method: Subject-Level Comparison

Different methods were used to analyse the alignment at subject level regarding learning outcomes, subject content, and demand. Each approach is outlined below.

3.3.1 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 subjects from the eleven comparison programmes.

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

3.3.2 Content

To compare the content of the DP subjects and the comparison subjects, these are presented 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 comparison subjects. 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 comparison subjects and on comparison subject content topics not found to have alignment points in the DP subjects.

3.3.3 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.[9]

- **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.[10]

- **Volume of Work** score (0-3): this is a trifactor score, considering:
  a. breadth of content – i.e. how many topics 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.[11]
  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. 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.[12]

Five expert panels were hosted to judge the demand levels of the science subjects in this series of studies, details of each panel are shown below:

[9] 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

[10] 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)

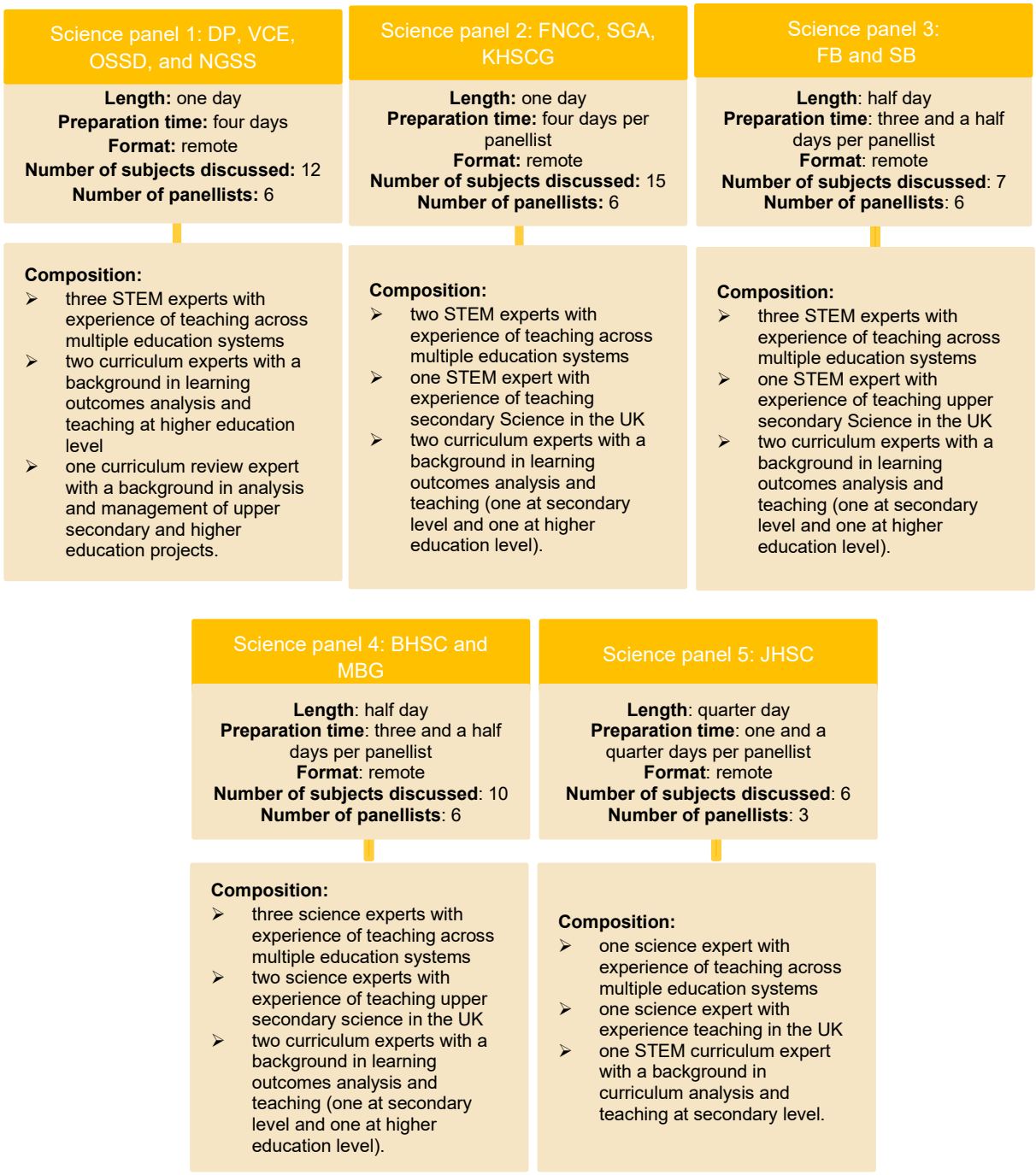
[11] Note: 'depth of content' primarily describes what is on the curriculum (i.e. the level of detail comprised in each topic), whereas 'depth of knowledge' describes what the students need to be able to do (i.e. how complex and extensive the thinking processes involved are).

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

1. Panel discussed the DP subjects and the subjects from the Victorian (Australia), Canadian (Ontario) and NGSS (US) curricula
2. Panel discussed the subjects from the Finnish (FNCC), Singaporean (SGA) and South Korean (KHSCG) curricula
3. Panel discussed the subjects from the French (FB) and Spanish (SB) curricula
4. Panel discussed the subjects from the Brazilian (BHSC) and Mexican (MBG) curricula
5. Panel discussed the subjects from the Japanese (JHSC) curriculum.

For each of these panels, the composition was as follows:

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 one 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 first two science demand panels lasted one full working day, whilst the third, fourth, and fifth panels had fewer subjects to consider and lasted half or quarter of a day each.

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.[13]

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.

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

4. Subject-Level Alignment

This section focuses on answering RQ1 and the sub-questions associated to it, namely:

Table 6: Research questions

RQ1: To what degree do the DP biology curricula align with the upper secondary biology curricula of the eleven comparison programmes? In what way are the curricula similar and in what way are they different? To what degree do the subjects align with regard to: 1.1: Content • Topics (i.e. scope of content area, breadth, depth) • Learning activities (i.e. difficulty, demand). 1.2: Expected learning outcomes • Knowledge • Competencies (i.e. subject-specific, 21st century competencies).

Each sub-section below includes a brief overview of the respective comparison programme/standards and the comparison subjects. This is followed by an overview of the findings from the comparative analysis between the DP subjects and the comparison points regarding learning outcomes, content, and demand.

4.1 DP Biology Overview

The Diploma Programme (DP) was established in 1968 as a two-year pre-university programme for 16–19-year-old students.[14]

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
- The arts.[15]

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 SL or HL. In terms of teaching hours, the DP's documentation recommends 150 teaching hours for individual subjects at SL and 240 teaching hours at HL.[16]

[14] International Baccalaureate. (2015). *Diploma Programme. From principles into practice*. p. 5.
[15] International Baccalaureate. (2025). *DP curriculum*. Available from: DP curriculum - International Baccalaureate®
[16] Ibid.

In addition to the six subjects taken from these groups, DP students will also need to complete three further curriculum components. Together, these three components comprise the DP 'core'. Theory of knowledge (TOK) allows students to reflect on the nature of knowledge by considering their subjects from a broader perspective.[17] The extended essay is a self-directed piece of research which results in a 4,000-word essay.[18] 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.[19]

To achieve the IB Diploma a student must take at least three HL subjects.[20] 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.[21]

As an optional subject, DP students may choose whether or not to study the DP biology course.

DP biology[22]

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.

[17] International Baccalaureate. (2025). *DP core*. Available from: DP core - International Baccalaureate®
[18] Ibid.
[19] Ibid.
[20] International Baccalaureate. (2025). *DP curriculum*.
[21] International Baccalaureate. (2015). *Diploma Programme. From principles into practice*. p.6.
[22] International Baccalaureate. (2023). *Biology guide*.

The visual below shows the structure of the DP biology subject. Students taking the HL subject will study both the standard level (SL) and additional higher level (AHL) content.

Figure 2: DP biology content visualiser[23]

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

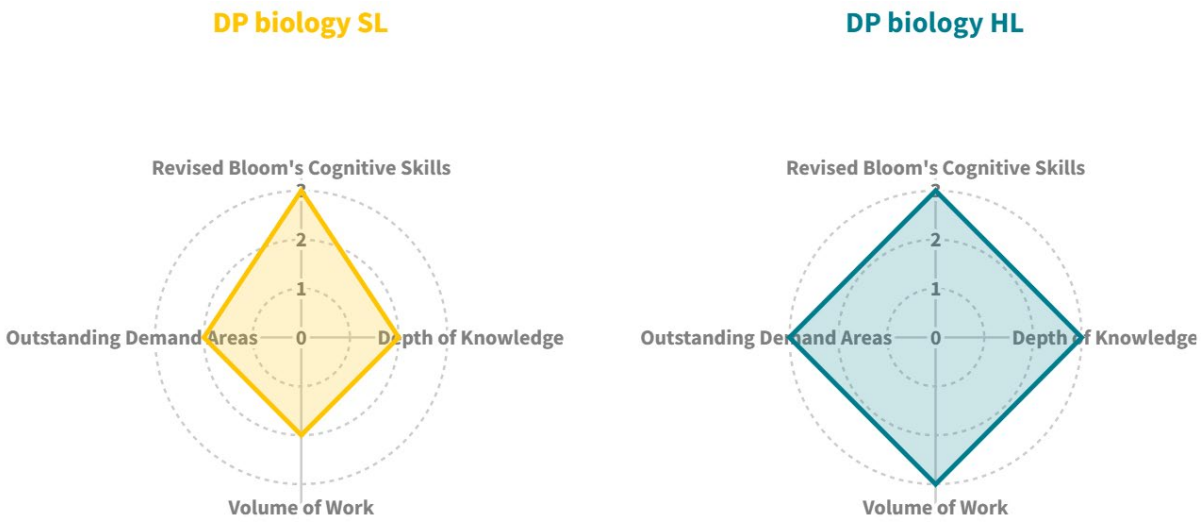
*Includes additional higher level (AHL) content.

[23] Unless specified as HL only, all the above are studied in SL and HL, with the latter also including the AHL content.

The analysis in this study compared the biology subjects of each comparison programme with the DP biology.

In order to assess demand alignment between the DP biology and the comparison subjects, demand profiles were created for the DP biology SL and DP biology HL. Each of these were scored (0-3) in four demand categories. Below, the profiles are presented as radar diagrams. These demand profiles will be used for comparison in the demand section of each country.

Figure 3: Visual representations of subject demand



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.

- Regarding the scores 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.

- 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.

- Regarding the scores for **Outstanding Areas of Subject Demand:**
  - For the DP biology SL course (awarded a score of 2), the research project that students need to undertake, the linking questions outlined in the syllabus and the collaborative sciences project were deemed to constitute 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.

4.2 Australia (Victoria)

The Victorian Certificate of Education (VCE) is awarded to students who successfully complete the last two years (11 and 12) of secondary education in the state of Victoria, Australia. This is typically achieved by successfully completing 16-24 units of study across a number of subjects. Each subject contains four units that last for one semester each and have a minimum scheduled classroom instruction time of 50 hours.[24] For most students, the VCE is completed over a two-year period. Students typically study Units 1 and 2 of each subject in their first year, and Units 3 and 4 in their second year.[25]

The VCE is flexible, meaning that students can take longer than two years to complete studies if needed. Alternatively, the VCE course can also be completed in a shorter or earlier timeframe – some students may opt to start studying the VCE in year 10, while some may study Units 3 and 4 in year 11.[26] Additionally, those who are identified as outstanding students may opt to extend their studies by undertaking a university subject within the VCE.[27]

Students have the option to study Unit 1 or Unit 2 of a subject as stand-alone units. However, students must enrol in Units 3 and 4 of the same subjects as a sequence. This sequence needs to be completed in the same year for the study score to be calculated.[28]

To be awarded the VCE, candidates must successfully complete 16 units, including:

- three units from the English group, two of which must be a Unit 3 and 4 sequence.
- at least three additional Unit 3 and 4 sequences.

As illustrated by the above, students are not required to study any biology as part of the VCE, but they have the option to do so if they wish.

VCE biology[29]
VCE biology is typically taken in the final two years of secondary education, Years 11 and 12 and includes four units of study. The units cover four inquiry led questions within biology – Unit 1 is focused on how organisms regulate their functions, while Unit 2 focuses on inheritance and its impact on diversity. Unit 3 asks the question 'How do cells maintain life?' and Unit 4 is centred on how life evolves and responds to challenges. There are no prerequisites for entry to Units 1, 2 and 3; however, students are required to have taken Unit 3 prior to Unit 4.

4.2.1 Learning Outcomes

The learning outcome themes for biology were taken 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 VCE curriculum sets out subject aims for the sciences, which detail a

[24] Victorian Curriculum and Assessment Authority. (n.d.). *How VCE Works – The Facts.* Available from: https://www.vcaa.vic.edu.au/studentguides/myvce/Pages/HowVCEWorks.aspx
[25] Ibid.
[26] Ibid.
[27] Ibid. No definition of what constitutes an 'outstanding student' is provided.
[28] Ibid.
[29] Victorian Curriculum and Assessment Authority. (2020). *Victorian Certificate of Education. Biology Study Design*. Available from: Pages - Biology (vcaa.vic.edu.au)

range of intended skills and competencies on a subject level. The VCE curriculum also sets out key science skills which specify the generic scientific competencies that students are expected to develop and demonstrate throughout all four biology units. These are included in the cross-study specifications section of the curriculum as they apply to science subjects in general. However, in contrast to the DP, the aims and key science skills in the VCE are contextualised for each individual science – though the main concepts remain the same.

As well as the aims and key science skills, the VCE curriculum includes biology-specific outcomes. Indeed, each 'area of study' in a biology unit contains three 'outcomes' – listing topic-specific statements that address key knowledge and key skills. This differs to the DP, which does not set out specific biology outcomes. However, since the VCE's sciences aims and key skills are detailed, the analysis mostly focuses on these, rather than the topic-specific outcomes in the areas of study of individual sciences.

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 VCE biology curricula.

Table 7: Presence of the DP sciences learning outcome themes in the VCE science/biology curricula

Themes extracted from the learning outcomes of the DP sciences subject group	Presence in VCE	
1. Conceptual understanding and making connections		Present. Developing understanding has a stronger focus in the aims of the recently updated biology curriculum
2. Acquisition and application of knowledge, methods, tools, and techniques that characterise science		Present. Found in both aims and key science skills
3. Creativity and critical thinking (problem-solving, analysis, evaluation, synthesis)		Present. Found in both aims and key science skills
4. Skills for scientific inquiry		Present. Found in both aims and key science skills
5. Development of technological skills		Present. Found in the key science skills
6. Effective collaboration and communication		Present. Found in both aims and key science skills
7. Awareness of global and local problems and the environmental, ethical, cultural, and social impact of science		Present. Found in both aims and key science skills

Key:

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

Presence of the DP's Learning Outcome Themes

The DP's learning outcome themes are found to be present in the aims and key science skills specified for all sciences – contextualised for biology. Application of scientific knowledge, methods, tools, and techniques are well evidenced in the VCE curricula. Examples of relevant key science skills from the VCE curriculum relating to application include 'solve a scientific or

technological problem' and 'select and use scientific procedures'. Explicit reference to scientific application is also evident in the VCE aims, which include 'apply these guidelines to generate, collate, analyse, critically evaluate and report data …'. Application, particularly in the context of problem solving, is also evident at unit level in outcomes which require the student to 'solve' and 'apply'.

Equally, the aims and key science skills strongly evidence the DP's theme of using creative and critical thinking, as references to analysing, evaluating, and problem-solving are frequently used throughout. Some specific examples relating to this theme are 'critically evaluate and interpret a range of scientific and media texts (including journal articles, mass media communications and opinions presented in the public domain)' and 'analyse and evaluate a bioethical issue in genetics, reproductive science or adaptations beneficial for survival'. Another strong theme in the VCE is that of developing science inquiry skills. The key science skills especially related to this theme include 'Develop aims and questions, formulate hypotheses and make predictions', 'Comply with safety and ethical guidelines', and 'Construct evidence-based arguments and draw conclusions'.

Communication and collaboration skills, as well as communication of scientific ideas, are referenced throughout the units of the VCE and are explicitly included in the aims and key science skills. For example, the VCE key science skills describe that a student should be able to 'acknowledge sources of information and use standard scientific referencing conventions' and develop 'a range of individual and collaborative science investigation skills'. Moreover, the aims state that students should be enabled to 'communicate clearly and accurately an understanding of the discipline using appropriate terminology, conventions and formats'.

Regarding the DP's theme of awareness of global and local issues and the ethical, environmental, societal, and cultural impact of science, the VCE curricula demonstrate this theme mostly in their aims. Indeed, the aims similarly state that students should 'develop an informed perspective on contemporary science-based issues of local and global significance'; 'understand the cooperative, cumulative, evolutionary and interdisciplinary nature of science as a human endeavour, including its possibilities, limitations and political and sociocultural influences'; and 'analyse and evaluate bioethical issues using relevant approaches to bioethics and ethical concepts, including the influence of social, economic, legal and political factors relevant to the selected issue'.

Finally, conceptual understanding, or indeed developing understanding, is also a focus of the aims and key science skills of VCE biology. Indeed, the aims in VCE biology state that students should:

- develop knowledge and understanding of key biological models, theories, concepts and issues from the individual cell to species level
- develop knowledge and understanding of organisms, their relationship to their environment, and the consequences of biological change over time, including the impact of human endeavours on biological processes and the survival of species
- develop knowledge and understanding of key models, concepts, theories and laws of science to explain scientific processes and phenomena, and apply this understanding

in familiar and unfamiliar situations, including personal, sociocultural, environmental and technological contexts

Additionally, it is also stated in the key science skills that students should 'discuss relevant biological information, ideas, concepts, theories and models and the connections between them'. Combining these statements together, it is clear that the VCE aims to develop understanding and allow for connections to be made in biology, although it can be noted that conceptual understanding is not explicitly referenced.

Other Themes in the VCE

Although mainly skills-focused, the VCE aims also provide additional detail on the attitudes and values intended to be developed in students throughout the study. For example, VCE students are supposed to 'develop attitudes that include curiosity, open-mindedness, creativity, flexibility, integrity, attention to detail and respect for evidence-based conclusions'. These attitudes fall outside of the scope of the DP learning outcome themes but may relate more to the attributes expressed in the IB learner profile, for example 'Risk Taker', 'Open-Minded' and 'Principled'.

Summary

The biology learning outcomes of the DP and VCE are highly aligned. The VCE learning outcomes have similar themes to the DP – including application, creativity and critical thinking, scientific inquiry skills, technological skills, effective communication and collaboration, and wider awareness of issues and impacts. Furthermore, the more recently revised biology curriculum places greater emphasis on the development of understanding.

Although there are many similarities, a notable difference is that the VCE includes a statement about the types of attitudes students should develop, while the DP does this through its IB learner profile.

4.2.2 Content

This section includes a comparison of the content of the DP and VCE biology curricula. To support visual comparison at-a-glance, the biology content in the VCE is presented below in a diagram that shows the key topics and sub-topics included.

Figure 4: VCE biology content visualiser

Unit 1: How do organisms regulate their functions?	Area of Study 1: How do cells function?	Cellular structure and function	The cell cycle and cell growth, death and differentiation		
	Area of Study 2: How do plant and animal systems function?	Functioning systems	Regulation of systems		
	Area of Study 3: How do scientific investigations develop understanding of how organisms regulate their functions?	On completion of this unit the student should be able to adapt or design and then conduct a scientific investigation related to function and/or regulation of cells or systems, and draw a conclusion based on evidence from generated primary data.			
Unit 2: How does inheritance impact on diversity?	Area of Study 1: How is inheritance explained?	From chromosomes to genomes	Genotypes and phenotypes	Patterns of inheritance	
	Area of Study 2: How do inherited adaptations impact on diversity?	Reproductive strategies	Adaptations and diversity		
	Area of Study 3: How do humans use science to explore and communicate contemporary bioethical issues?	On completion of this unit the student should be able to identify, analyse and evaluate a bioethical issue in genetics, reproductive science or adaptations beneficial for survival.			
Unit 3: How do cells maintain life?	Area of Study 1: What is the role of nucleic acids and proteins in maintaining life?	The relationship between nucleic acids and proteins	DNA manipulation techniques and applications		
	Area of Study 2: How are biochemical pathways regulated?	Regulation of biochemical pathways in photosynthesis and cellular respiration	Photosynthesis as an example of biochemical pathways	Cellular respiration as an example of biochemical pathways	Biotechnological applications of biochemical pathways
	Area of Study 3: School-based assessment	The student's level of achievement in Unit 3 is determined by School-assessed Coursework. Coursework tasks are completed mainly in class and within a limited timeframe.			
Unit 4: How does life change and respond to challenges?	Area of Study 1: How do organisms respond to pathogens?	Responding to antigens	Acquiring immunity	Disease challenges and strategies	
	Area of Study 2: How are species related over time?	Genetic changes in a population over time	Changes in species over time	Determining the relatedness of species	Human change over time
	Area of Study 3: How is scientific inquiry used to investigate cellular processes and/or biological change?	On completion of this unit the student should be able to design and conduct a scientific investigation related to cellular processes and/or how life changes and responds to challenges, and present an aim, methodology and methods, results, discussion and a conclusion in a scientific poster.			

4.2.2.1 Structure

The VCE biology curriculum features only one pathway, with students studying all the topics to the same level of detail. In contrast, the DP biology provides two routes for learning, SL and HL, with the HL biology content being more conceptually demanding and explored in greater depth.

The VCE biology course is arranged into four units spanning the course of two years. Within each unit, there are up to three areas of study, with Area of Study 1 focusing on acquisition of knowledge and subsequent areas featuring a greater focus on application of knowledge and practical investigations. These units are prefaced with the expected science skills and how students should communicate their understanding from investigations.

Similar to VCE biology, DP biology provides guiding questions, but is mainly organised using four themes (A. Unity and diversity, B. Form and function, C. Interaction and interdependence, and D. Continuity and change) that are explored at four levels (Molecules, Cells, Organisms, and Ecosystems). Each level is broken down into topics. There is a total of 16 levels and 35 topics in the SL course and 40 topics in the HL. All topics contain components that incorporate key understandings, learning outcomes, and links to the 'Skills of the study of biology' and 'Nature of science'.

There are some differences in how the content and knowledge areas are structured. In the VCE biology, the design of the programme is centred around inquiry questions so the content that follows naturally relates to the question being asked which is specific to the theme of each unit. There is minor overlap between units, but in the most part prerequisite knowledge from one unit is not required in order to progress onto the next. In the DP, however, content is organised in a more sequential fashion, with fundamental knowledge in the SL core subsequently being built upon in the HL topic areas. An example of this progressive nature of the DP is in regard to homeostasis, where the fundamentals are covered in the SL core and more advanced and detailed knowledge of the biological and chemical processes involved is subsequently covered in later HL topics.

4.2.2.2 Content Alignment

To complement the analysis on content alignment, the table below represents a simplified summary of the VCE's content alignment with the themes and levels in DP biology (SL and HL).

Table 8: Summary of content alignment between DP biology and VCE biology

DP biology themes and levels	Presence of SL content in the VCE	Presence of AHL content in the VCE
A Unity and diversity		
A1 Molecules		
A2 Cells		
A3 Organisms		
A4 Ecosystems		
B Form and function		
B1 Molecules		
B2 Cells		
B3 Organisms		
B4 Ecosystems		N/A

C Interaction and interdependence		
C1 Molecules		
C2 Cells		
C3 Organisms		
C4 Ecosystems		N/A
D Continuity and change		
D1 Molecules		
D2 Cells		
D3 Organisms		
D4 Ecosystems		
Experimental programme		

Key:

	Strong presence of this level in the VCE		*Partial presence of this level in the VCE*		*Little or no presence of this level in the VCE*

There is substantial content alignment between VCE biology and DP biology SL, with only seven out of the 35 topics in DP SL being absent from the VCE biology curriculum. These topics are: carbohydrates and lipids, transport, ecological niches, neural signalling, transfers of energy and matter, sustainability and change, and climate change. However, some SL topics are covered by the VCE in a lower amount of detail and depth, including: proteins, membranes and transport, gas exchange, adaptation to environment, integration of body systems, populations and communities, mutations and gene editing, and reproduction.

The VCE course does cover some of the AHL content present in the HL course, though not always in the same depth. In particular, the VCE features some coverage of two out of five HL-only topics – viruses and gene expression – though this coverage is relatively limited, for example, viruses only seem to be briefly covered when studying the consequences of viral antigenic drift and shift, while the HL treats viruses as a topic in itself, covering viral structures as well as lytic and lysogenic cycles. The remaining three HL-only topics – muscle and mobility, chemical signalling and origins of cells – are largely absent from the VCE, as is the AHL content across a number of topics, namely water, nucleic acids, evolution and speciation, membranes and membrane transport, cell specialisation, gas exchange, transport, neural signalling, integration of body systems, reproduction, homeostasis, sustainability, and change and climate change.

In summary, while there is substantial alignment between the DP and the VCE biology curricula, the latter has stronger content alignment with the SL course in breadth and depth, with the HL course covering more topics in more depth.

Table 9: VCE biology content which is not covered in the DP

Significant VCE biology content which is not included in the DP*
○ No significant VCE biology content was found to be absent from the DP biology course.

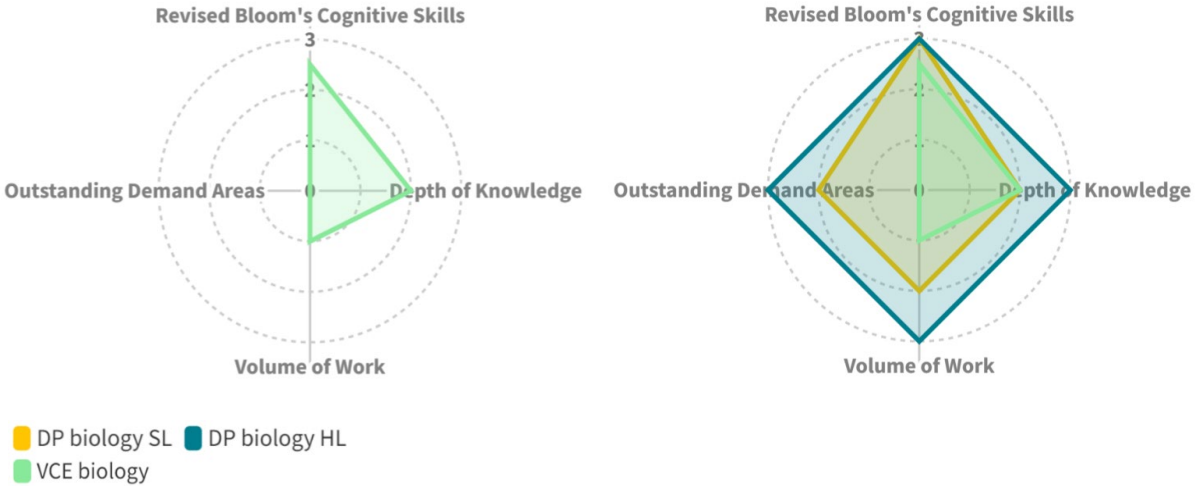
* Significant content mostly does not include topics which are typically studied *prior* to upper secondary

4.2.3 Demand

The DP and VCE curricula were analysed using the same demand tool in order to create a demand profile for DP biology SL, DP biology HL, and VCE biology. These demand profiles

are presented below in the form of radar diagrams, with the last diagram showing all profiles superimposed in one place, enabling immediate visual comparison.

Figure 5: Visual representations of subject demand



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**:
  - Both DP biology SL and HL received a score of 3.
  - For VCE biology, a score of 2.5 was awarded, with Units 1 and 2 deemed to meet a score of 2 and Units 3 and 4 scores of 3. There was agreement that the learning outcomes featured a solid focus on analysis and evaluation, methods and scientific models and that some synthesis and creation skills (in the form of investigation and research) were included too, though this was not deemed to be sufficient to meet a score of 3.

- Regarding the score for **Depth of Knowledge**:
  - DP biology SL received a score of 2 and HL received a score of 3.
  - For VCE biology, the cognitive complexity and detail of the topics studied in the course, the (non-explicit) pre-requisites for accessing Units 1 and 2 and explicit pre-requisites for accessing Units 3 and 4, as well as a predominant focus on application of knowledge, were deemed to merit a score of 2.

- Regarding the scores for **Volume of Work**:
  - DP biology SL received a score of 2 and HL received a score of 3.
  - In contrast, the VCE biology course was attributed a score of 1 (moderate) due to the comparatively generous time allocation provided per topic studied.

- Regarding the scores for **Outstanding Areas of Subject Demand**:
  - DP biology SL received a score of 2 and HL received a score of 3.
  - For VCE biology, a score of 0 was given as no particular stretch areas were identified for the course.

4.3 Canada (Ontario)

The school system in the Canadian province of Ontario is overseen by the Ontario Ministry of Education. It is divided into primary school (grades 1-8) and secondary school (grades 9-12), with each grade being a year in duration.[30]

The Ontario Secondary School Diploma (OSSD) spans the last four years of Ontario's secondary school education, grades 9-12. Beginning in grade 9, students take courses to earn credits towards the OSSD, which is intended to grant access to higher education upon successful completion. There are several credit, and other, requirements, to gain the OSSD.

To earn a high school diploma in Ontario, students must:

- Earn a minimum of 30 credits, including 18 compulsory credits (see table below) and 12 optional credits selected from the courses listed as available in their school's programme and course calendar.
- Meet the provincial secondary school literacy requirement (i.e. usually, this means passing the Ontario Secondary School Literacy Test[31])
- Complete a minimum of 40 hours of community involvement activities (a requirement aimed to provide students the opportunity to develop awareness and understanding about civic responsibility).[32]

Table 10: Compulsory credits for attaining the OSSD

Compulsory credits for attaining the OSSD (Total of 18)
• 4 credits in English (1 credit per grade) • 3 credits in mathematics (at least 1 credit in grade 11 or 12) • 3 credits for group 1, 2 and 3 courses (1 credit in each group) • 2 credits in science • 1 credit in Canadian history (grade 10) • 1 credit in Canadian geography (grade 9) • 1 credit in the arts • 1 credit in health and physical education • 1 credit in French as a second language • 0.5 credit in career studies • 0.5 credit in civics and citizenship

Courses are not only categorised by subject, but also by the stream within which they sit.

Types of courses available:

- Grades 9 and 10 – courses will be either 'Academic', 'Applied', or 'Open'. More recently, some subjects that were previously streamed in grade 9 have now been de-streamed.[33]
- Grades 11 and 12 – courses will be either 'University Preparation', 'College Preparation', 'University/College Preparation', 'Workplace', or 'Open'.

[30] Government of Ontario, Ministry of Education. (2020). *Education and Training*. Available from: https://www.ontario.ca/page/educationand-training
[31] Education Quality and Accountability Office. (n.d.). *Ontario Secondary School Literacy Test (OSSLT)*. Available from: https://wwweqao.com/the-assessments/osslt/
[32] Government of Ontario, Ministry of Education. (2020). *High school graduation requirements*. Available from: https://wwwontario.ca/page/high-school-graduation-requirements#section-3
[33] Meaning that, for grade 9 core courses, students no longer choose between the Academic and Applied levels.

The analysis for Ontario focuses on the science courses offered in grades 9 and 10 and the biology grade 11 and grade 12 University Preparation (UP) courses. For content and demand, the analysis focuses on how grade 11 and grade 12 courses align with the DP, due to grades 9 and 10 being more typical of learning prior to upper secondary biology.

OSSD grades 9 and 10 science: Academic[34]
Grades 9 and 10 are split into two streams, Academic and Applied. For the purposes of this report, the Academic stream and following courses will be the focus. The different areas of science are integrated at this grade to include concepts in chemistry, biology, physics, and earth and space science. The academic stream develops students' skills through the study of theory and abstract problems, whereas the applied stream emphasises practical applications. Students need to study the grade 10 Academic course to be able to access UP biology courses.

OSSD grades 11 and 12 biology: University Preparation[35]
Grades 11 and 12 offer University Preparation courses, University/College Preparation courses, College Preparation courses, and Workplace courses. For the purposes of this report, the courses offered in University Preparation will be the focus. Biology is offered as a course from grade 11 and can be continued onto grade 12. These courses are intended to prepare students for further study and enable progression to higher education in biology-related subjects.

4.3.1 Learning Outcomes

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

The learning outcome themes for biology were taken 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 OSSD sets out three goals which are the same for all science courses. These goals inform the three overall expectations found in each strand of a course; they also underlie assessment of student achievement.
The OSSD goals are the following:

- Goal 1. To relate science to technology, society, and the environment.
- Goal 2. To develop the skills, strategies, and habits of mind required for scientific investigation.
- Goal 3. To understand the basic concepts of science.

Each of the goals above had descriptions which were used for the analysis. Goal 2 was elaborated on in the section 'Developing Skills of Investigation and Communication', thus these details were also used.

[34] Government of Ontario, Ministry of Education. (2008). *The Ontario Curriculum Grades 9 and 10 Science.* Available from: The Ontario Curriculum, Grades 9 and 10: Science, 2008 (revised) (gov.on.ca).
[35] Government of Ontario, Ministry of Education. (2008). *The Ontario Curriculum Grades 11 and 12 Science.* Available from: The Ontario Curriculum, Grades 11 and 12: Science, 2008 (revised) (gov.on.ca)

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 OSSD biology curricula.

Table 11: Presence of the DP sciences learning outcome themes in the OSSD science/biology curricula

Themes extracted from the learning outcomes of the DP sciences subject group	Presence in Ontario's (OSSD) learning outcomes for science	
1. Conceptual understanding and making connections		Mostly present. Conceptual knowledge is referred to in Goal 3. Making connections is referred to in Goal 1, but with regard to the real-world, rather than within science.
2. Acquisition and application of knowledge, methods, tools, and techniques that characterise science		Present. Goal 3 deals with acquisition of knowledge and theme is implied in other Goals
3. Creativity and critical thinking (problem-solving, analysis, evaluation, synthesis)		Present. Critical and creative thinking skills are focused on in Goal 2.
4. Skills for scientific inquiry		Present. Skills for scientific inquiry are the focus of Goal 2
5. Development of technological skills		Present. Goal 1 describes 'technical literacy'
6. Effective collaboration and communication		Mostly present. Communication is focused on in Goal 2, however collaboration is not explicitly mentioned.
7. Awareness of global and local problems and the environmental, ethical, cultural, and social impact of science		Present. Relating science to technology, society and the environment is the focus of Goal 1

Key:

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

Presence of the DP's Learning Outcome Themes

As can be seen from the table above, all the DP's learning outcome themes are present in the OSSD, with only a couple of small differences. Firstly, the DP's theme regarding global and local issues and scientific implications is strongly evident in the OSSD. Indeed, designed to emphasise scientific, environmental, and technological literacy, Goal 1 focuses on relating science to technology, society, and the environment. From references to 'technological literacy' it follows that another of the DP's themes, developing technological skills, is also present in Goal 1.

Furthermore, the OSSD places similar significance on skills for scientific inquiry through Goal 2, which includes 'Developing Skills of Investigation and Communication'. There are four broad areas in which these skills are developed, namely 'Interpreting and planning', 'Performing and recording', 'Analysing and interpreting', and 'Communication'. As well as combining to satisfy the DP's theme of scientific inquiry skills, some of these areas also evidence other themes. For example, 'Analysis and interpreting' and 'Interpreting and planning' detail skills such as brainstorming, formulating hypotheses, making predictions, thinking critically and logically, evaluating and analysing data, solving problems, drawing and justifying conclusions, and synthesis – thus the DP's theme of creativity and critical thinking is well evidenced in the

OSSD. Furthermore, the area of 'Communication' details skills such as attention to detail, applying correct terminology, and using various forms and formats to communicate scientific ideas, information and results, hence the DP's theme of effective communication is well evidenced here. However, it can be noted that collaboration is not explicitly mentioned in the OSSD outcomes, although there is reference to oral communication.

Additionally, the DP's theme of using and applying knowledge, methods, tools, and techniques is not an explicit outcome in the OSSD but is obviously implied throughout the Goals. Finally, Goal 3 refers to 'conceptual knowledge' students are expected to understand, which aligns with the DP's theme regarding conceptual understanding. Moreover, making connections is a feature within the OSSD's outcomes; however, emphasis is on connections to the real-world, rather than within and between scientific disciplines.

Other Themes in the OSSD

Although the OSSD sets out goals which are applicable to all science courses, unlike the DP it also presents specific overall expectations within each course. Each course is split into strands, each of which have three overall expectations, informed by the goals. When contextualising the goals with courses' overall expectations, one immediate difference which emerges is that the OSSD has a clear focus on Canadians' contributions to the field, and the recognition of indigenous peoples' knowledge and customs. This focus gives the OSSD science courses a more nationalistic rooted identity, whereas the DP outcomes are framed around global and international perspectives.

Furthermore, an overall expectation which is common to all science courses in the OSSD is 'identify and describe careers related to the fields of science under study to those fields', hence the OSSD outcomes explicitly expect students to show an understanding of the careers that study of science can relate/lead to. By contrast, the DP's learning outcomes do not make this explicit link to careers, thus the OSSD emphasises the movement between study and the workplace more. However, by the nature of the OSSD UP courses and the DP, both have a focus towards further tertiary study. This would be accessing university level courses majoring in biology or related subjects.

Summary

The science learning outcomes of the DP and OSSD are highly aligned. The programmes contain very similar learning outcome themes for their science courses, with only small differences emerging.

4.3.2 Content

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

Figure 6: Ontario science grades 9-10 content visualiser

Science, grade 9, Academic	**Biology**	Ecosystems consist of a variety of components, including, in many cases, humans.	The sustainability of ecosystems depends on balanced interactions between their components.	Human activity can affect the sustainability of aquatic and terrestrial ecosystems.	
	Chemistry	Elements and compounds have specific properties that determine their uses.	The use of elements and compounds has both positive and negative effects on society and the environment.		
	Earth and Space Science	Celestial objects in the solar system and universe have specific properties that can be investigated and understood.	Technologies developed for space exploration have practical applications on Earth.		
	Physics	Electricity is a form of energy produced from a variety of non-renewable and renewable sources.	The production and consumption of electrical energy has social, economic, and environmental implications.	Static and current electricity have distinct properties that determine how they are used.	
Science, grade 10, Academic	**Biology**	Plants and animals, including humans, are made of specialized cells, tissues, and organs that are organized into systems.	Developments in medicine and medical technology can have social and ethical implications.		
	Chemistry	Chemicals react with each other in predictable ways.	Chemical reactions may have a negative impact on the environment, but they can also be used to address environmental challenges.		
	Earth and Space Science	Earth's climate is dynamic and is the result of interacting systems and processes.	Global climate change is influenced by both natural and human factors.	Climate change affects living things and natural systems in a variety of ways.	People have the responsibility to assess their impact on climate change and to identify effective courses of action to reduce this impact.
	Physics	Light has characteristics and properties that can be manipulated with mirrors and lenses for a range of uses.	Society has benefited from the development of a range of optical devices and technologies.		

Figure 7: Ontario biology grades 11-12 content visualiser

Biology, grade 11, University Preparation	**Diversity of Living Things**	All living things can be classified according to their anatomical and physiological characteristics.	Human activities affect the diversity of living things in ecosystems	
	Evolution	Evolution is the process of biological change over time based on the relationships between species and their environments	The theory of evolution is a scientific explanation based on a large accumulation of evidence	Technology that enables humans to manipulate the development of species has economic and environmental implications
	Genetic Processes	Genetic and genomic research can have social and environmental implications	Variability and diversity of living organisms result from the distribution of genetic materials during the process of meiosis	
	Animals: Structure and Function	Groups of organs with specific structures and functions work together as systems, which interact with other systems in the body	The development and uses of technology to maintain human health are based, in part, on the changing needs of society.	
	Plants: Anatomy, Growth, and Function	Plants: Anatomy, Growth, and Function Plants have specialized structures with distinct functions that enable them to respond and adapt to their environment.	Plant variety is critical to the survival and sustainability of ecosystems	
Biology, grade 12, University Preparation	**Biochemistry**	Technological applications that affect biological processes and cellular functions are used in the food, pharmaceutical, and medical industries.	Biological molecules and their chemical properties affect cellular processes and biochemical reactions	Biochemical compounds play important structural and functional roles in cells of all living organisms
	Metabolic Processes	All metabolic processes involve chemical changes and energy conversions.	An understanding of metabolic processes enables people to make informed choices with respect to a range of personal, societal, and environmental issues.	
	Molecular Genetics	DNA contains all the genetic information for any living organism.	Proteins control a wide variety of cellular processes.	Genetic research and biotechnology have social, legal, and ethical implications.
	Homeostasis	Organisms have strict limits on the internal conditions that they can tolerate.	Systems that maintain homeostasis rely on feedback mechanisms.	Environmental factors can affect homeostasis
	Population Dynamics	Population growth follows predictable patterns.	The increased consumption of resources and production of waste associated with population growth result in specific stresses that affect Earth's sustainability.	Technological developments can contribute to or help offset the ecological footprint associated with population growth and the consumption of natural resources

4.3.2.1 Structure

The Ontario curriculum for grades 9 and 10 offers general science study split into academic and applied content. In grades 11 and 12, students can choose between specific subjects (e.g. biology, chemistry, physics, earth and space science) and, within those subjects, can choose between destination-related courses depending on their post high school ambitions (e.g. university preparation, university/college preparation, college preparation, and workplace preparation courses). There are prerequisites to have completed some of the grade 9 and 10 courses to progress to grade 11 and 12 courses, but these differ depending on the destination-related course a student chooses to study – e.g. completion of either the academic or the applied grade 9 course allows students to proceed directly to the grade 11 workplace preparation course. The Ontario courses outlined in the grades 9 to 12 science curriculum documents are designed as full-credit courses (100 hours of study). However, except for the grade 12 university preparation and university/college preparation courses, they may also be delivered as half-credit courses (50 hours of study).

By comparison, progression through DP biology is simpler – the only pre-requisite stated for DP study is to have covered SL content before progressing to HL content and, if a student wishes to study HL, it is advisable that they have some prior scientific knowledge.

Both courses emphasise, and provide opportunities for, investigation and experimentation. The DP biology course stipulates that students should show awareness of the purpose and practice of ten biology techniques, outlined in Tool 1: Experimental Techniques, and the OSSD biology share coverage of six of those techniques, with exception of paper chromatography, colorimetry or spectrophotometry, serial dilutions or cladogram analysis.

Additionally, 30% of the final assessment in the OSSD courses is in the form of an examination, performance, essay, and/or other method of evaluation suitable to the course content and administered towards the end of the course, which could provide scope for an extended, self-directed investigation. However, the assessment method and scope vary from school to school and may not always, as a result, be comparable to the opportunities for investigation given to DP students through their IAs and collaborative sciences project.

4.3.2.2 Content Alignment

The rest of the biology analysis will focus on grades 11 and 12, rather than grades 9 and 10. Indeed, the studies in the first two years of the OSSD are more typical of learning *prior* to upper secondary, hence there is alignment with these grades and more meaningful comparisons to the DP can be drawn from the last two years of Ontario's secondary school education.

To complement the analysis on content alignment, the figures below represent a simplified summary of the OSSD's content alignment with the themes and levels in DP biology (SL and HL).[36]

[36] The content of grades 9 and 10 was also mapped but is not represented in the table. Very little alignment was found with these grades due to their content being more typical of prior learning to upper secondary biology.

Table 12: Summary of content alignment between DP biology and OSSD grade 11 (university preparation)

DP biology themes and levels	Presence of SL content in the OSSD grade 11 biology	Presence of AHL content in the OSSD grade 11 biology
A Unity and diversity		
A1 Molecules		
A2 Cells		
A3 Organisms		
A4 Ecosystems		
B Form and function		
B1 Molecules		
B2 Cells		
B3 Organisms		
B4 Ecosystems		N/A
C Interaction and interdependence		
C1 Molecules		
C2 Cells		
C3 Organisms		
C4 Ecosystems		N/A
D Continuity and change		
D1 Molecules		
D2 Cells		
D3 Organisms		
D4 Ecosystems		

Table 13: Summary of content alignment between DP biology and OSSD biology grades 11 and 12 combined (university preparation)

DP biology themes and levels	Presence of SL content in the OSSD	Presence of AHL content in the OSSD
A Unity and diversity		
A1 Molecules		
A2 Cells		
A3 Organisms		
A4 Ecosystems		
B Form and function		
B1 Molecules		
B2 Cells		
B3 Organisms		
B4 Ecosystems		N/A
C Interaction and interdependence		
C1 Molecules		
C2 Cells		
C3 Organisms		
C4 Ecosystems		N/A
D Continuity and change		
D1 Molecules		
D2 Cells		
D3 Organisms		
D4 Ecosystems		
Experimental programme		

Key:

	Strong presence of this level in the OSSD		*Partial presence of this level in the OSSD*		*Little or no presence of this level in the OSSD*

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

There is a high level of content alignment between the DP biology and OSSD biology courses, with both courses dedicating a substantial amount of learning hours to cells, molecules, genetics, ecology, evolution, plants, and animals/humans.

The DP SL covers all significant content in the OSSD biology course, and the latter covers all significant content in the DP SL course, with exception of water – which is absent from the OSSD – and climate change, which is covered in less detail.

When it comes to the HL, there is also significant overlap but a number of areas in the DP's AHL content exceeds the OSSD in both breadth and depth. For example, the OSSD does not feature comparable coverage of the AHL content on cell structure and respiration, evolution and speciation, protein synthesis, membranes and transport, cell specialisation, reproduction, homeostasis and genes, and it also does not cover muscle and mobility or chemical signalling.

Overall, there is a high level of alignment in the core content covered within both courses, while there is also evidence that the HL topics in the DP involve greater breadth or depth in specific areas.

Table 14: OSSD biology content which is not covered in the DP

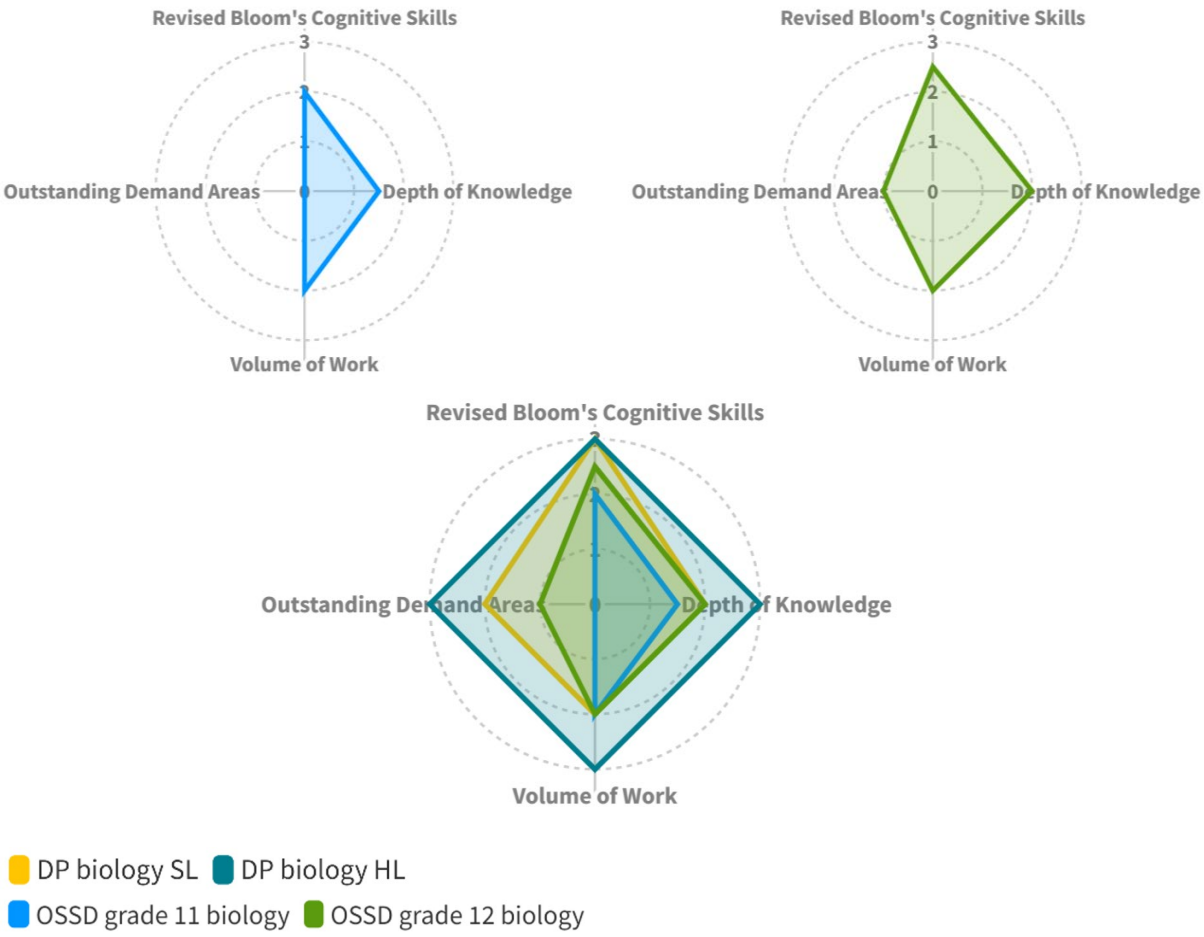
Significant OSSD biology content which is not included in the DP*
○ All significant content is covered by DP biology.

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

4.3.3 Demand

The DP and OSSD curricula were analysed using the same demand tool in order to create a demand profile for DP biology SL, DP biology HL, science, OSSD grade 11 biology, and OSSD grade 12 biology. These demand profiles are presented below in the form of radar diagrams, with the last diagram showing all profiles superimposed in one place, enabling immediate visual comparison.

Figure 8: Visual representations of subject demand



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**:
  - Both DP biology SL and HL received a score of 3.
  - A score of 2 was awarded to OSSD grade 11 biology due to the course's solid emphasis on evaluations and investigation, but only limited presence of creation-focused learning outcomes. For grade 12 biology, though a considerable number of learning outcomes still focused on application, a more substantial focus on analysis of information and data was observed, meriting a 2.5 Bloom's demand score.

- Regarding the score for **Depth of Knowledge**:
  - DP biology SL received a score of 2 and HL received a score of 3.
  - OSSD grade 11 biology was judged to merit a score of 1.5 due to the considerable detail and complexity of the material students are expected to study (including the expectation that students consider the ethical implications of science investigation) and pre-requisite knowledge from grade 10. OSSD grade 12 biology, in turn, was given a score of 2 as, although the primary focus of the course was still found to

be on knowledge application rather than more complex reasoning, many topics were found to be studied in higher detail. The lack of clear opportunities for higher-order thinking prevented the course from achieving a score of 3.

- Regarding the scores for **Volume of Work**:
  - DP biology SL received a score of 2 and HL received a score of 3.
  - For Ontario grade 11 and grade 12 biology, a score of 2 was awarded. Both courses were seen to include added depth of content (when compared to their pre-secondary counterparts) and although students only study six units of work, the number of themes and concepts covered was judged to be typical to high and the time allocation per topic was considered standard.

- Regarding the scores for **Outstanding Areas of Subject Demand**:
  - DP biology SL received a score of 2 and HL received a score of 3.
  - For OSSD grade 11 biology no clear stretch areas were found. For grade 12 biology, the D1.2 research task (focused on analysis of key aspects of Canadian regulations pertaining to biotechnology and comparing to regulations from other jurisdictions) was judged to be a stretch area, awarding the course a score of 1 for this category.

4.4 Finland

The school system in Finland is overseen by the Finnish National Agency for Education (EDUFI).[37] Compulsory education is divided into Basic Education (years 1-9) and General Upper Secondary Education (GUSE). In Finland, students must study until they graduate from secondary education or reach the age of eighteen.[38] GUSE is typically three years in duration, yet students may complete the certificate in two or four years; as a result, the qualification is very fluid and there are no grade-specific classes.

An extensive reform to GUSE was launched in 2017, with changes to the Act on GUSE and the Government Decree on GUSE.[39] The aforementioned documents form the basis of the Finnish National Core Curriculum (FNCC), produced by EDUFI, with input from teaching staff, students, students' guardians, and relevant authorities. The FNCC underpins all local curriculum offerings.

In the FNCC/GUSE, each subject area is composed of different *subjects*, some of which contain different choices of *syllabi* – e.g. biology has only one syllabus, while mathematics offers two syllabi for student to choose from. Subjects/syllabi, in turn, contain *studies* (also referred to as 'modules'). There are *compulsory studies* and *national optional studies* – each study carrying different credit values.

In order to complete general upper secondary education, students must have 'passed the subject syllabi and completed the minimum scope of general upper secondary education studies, or 150 credits'.[40] Of these 150 credits, a minimum of 20 must have been obtained from the completion of national optional studies. For reference, each credit is equivalent to fourteen hours and fifteen minutes of teaching, in addition to independent study.[41]

Students must study the *compulsory credits* from all of the subjects listed in the table below.

Table 15: List of subjects and compulsory credits in the FNCC[42]

Subjects and their compulsory credits in the FNCC
• mother tongue and literature (12 credits) • second national language, either Finnish or Swedish. (10 or 12 credits)* • foreign languages (12 credits) • mathematics (12 or 20 credits)* • biology (4 credits) • physics (2 credits) • chemistry (2 credits)

[37] Finnish National Agency for Education. (2022). Available from: https://www.oph.fi/en
[38] Ministry of Education and Culture, Finland. (2020). *Act on Compulsory Education (1214/2020).* Available from: https://www.finlex.fi/fi/laki/ajantasa/2020/20201214
[39] Finnish National Agency for Education. (2019). *National Core Curriculum for General Upper Secondary Education*. p. 10.
[40] Ibid. p. 62.
[41] Ministry of Education and Culture, Finland. (2018). *Government Decree on General Upper Secondary Education (810/2018).* Available from: https://www.finlex.fi/fi/laki/alkup/2018/20180810
[42] Finnish National Agency for Education. (2019). *National Core Curriculum (NCC) for General Upper Secondary Education*.

Subjects and their compulsory credits in the FNCC
• geography (2 credits) • philosophy (4 credits) • psychology (2 credits) • history (6 credits) • social studies (6 credits) • religion or worldview studies (4 credits) • health education (2 or 4 credits)* • physical education (4 credits) • music (4 credits) • visual arts (2 or 4 credits)* • guidance counselling (4 credits). * Depending on the syllabus chosen.

As can be seen from the table above, students are required to study biology as part of the FNCC/GUSE.

FNCC biology[43]

The Finnish National Agency for Education provides a framework on which local education establishments put together their curriculum. Each science discipline is composed of 'compulsory' and 'optional' studies (or modules). Students are required to study all compulsory studies, but they have free choice over which, if any, optional studies they take. Through the biology curriculum students will develop an interest in life and environmental sciences and understand the structure, function and interrelationships of the natural world. Students will obtain a picture of life sciences as rapidly developing disciplines which have uses in many fields, such as medical science, industry, agriculture and forestry. The teaching and learning of biology are integrated with other subjects, such as geography, chemistry, physics, psychology and health education.

4.4.1 Learning Outcomes

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

The learning outcome themes for biology were extracted from the aims and assessment objectives of the DP sciences subject group, hence the themes are the same for biology chemistry and physics.

The FNCC outlines a 'task of the subject' section which provides overarching ideas about the intended development of students' knowledge and understanding in each subject. Additionally, the FNCC includes a section on 'general objectives of Instruction of biology' which is further broken down into three sub-sections: 'Biological approach', 'Biological phenomena and processes' and 'Biological skills and their application', each of which has its own objectives. An 'Assessment Framework' section is also included, providing general information regarding what skills students should be assessed on. Finally, the FNCC also includes a section on 'Transversal Competencies in the Subject' which describes how the philosophical

[43] Finnish National Agency for Education. (2019). *NCC for General Upper Secondary Education.*

underpinnings of the FNCC are integrated within the instruction of biology as a subject – including societal competence, interaction competence, ethical and environmental competence, global and cultural competence, multidisciplinary and creative competence, as well as well-being. Notably, the FNCC as a whole has a very holistic approach and puts particular emphasis on the integration of wider skills into their biology curriculum, and a lesser focus on subject content and subject-specific scientific knowledge.

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 FNCC biology curricula.

Table 16: Presence of the DP sciences subject group learning outcome themes in the FNCC biology curricula

Themes extracted from the learning outcomes of the DP sciences subject group	Presence in FNCC	
1. Conceptual understanding and making connections		Present in all areas through the description of biology underpinning understanding of the interrelationships of the natural world and the cross-over of phenomena within biology being examined in other subjects such as geography, chemistry and psychology.
2. Use and application of knowledge, methods, tools, and techniques that characterise science		Present in transversal competences through the description of the ways of knowledge building in biology and the disciplines associated with it, alongside the language and terminology of biology.
3. Creativity and critical thinking (problem-solving, analysis, evaluation, synthesis)		Present in transversal competences and general objectives. The FNCC describes students learning to present arguments and evaluate people's views, as well as adopting an enquire-based approach.
4. Skills for scientific inquiry		Present in the task of the subject through reference to information acquired based on observations, experiments, research-based practices and working methods that are both active and interactive.
5. Development of technological skills		Present. As mentioned in the task of the subject, teaching and learning involve laboratory work and work in digital environments.
6. Effective collaboration and communication		Present in transversal competences and general objectives. Students will work in groups to learn to present arguments and develop their social and interaction skills.
7. Awareness of global and local problems and the environmental, ethical, cultural, and social impact of science		Present. This theme is strongly emphasis in the FNCC and is therefore present in all areas. There are many references to the importance of biodiversity and how students develop environmental competence as well as finding the initiative to act for positive solutions.

Key:

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

Presence of the DP's Learning Outcome Themes

As can be seen in the table above, all learning outcome themes extracted from the DP are well evidenced in the FNCC, apart from one – development of technological skills.

Conceptual understanding is evident from the emphasis placed by the general objectives on knowing 'how to use key concepts in biology accurately and in correct contexts', as well as 'understand biological causal relations', 'command of basic concepts of biology and their reflection, justification, and research skills', and acquiring 'skills for…further studies'. Making connections is evident from statements such as 'adopt a…multidisciplinary and creative way of working', 'understand the structure, function and interrelationships of the natural world…engage in versatile cooperation with other subjects' and '…knowledge building in biology and the disciplines associated with it'. This is also well-evidenced in the Assessment Framework, which states that assessment should focus on 'understanding of the fundamental principles of natural sciences and causal relations, their grasp of the importance of interrelationships, and their ability to perceive the whole'.

The use and application of methods, tools and techniques that characterise science is also more implied than explicitly stated in the general objectives – 'the ways of knowledge building in biology and the disciplines associated with it'. In the 'task of the subject' section, it is alluded to in statements such as: 'Information acquisition based on observations and experiments, research-based practises, and working methods that are both active and interactive'.

Creativity and critical thinking are referenced throughout all strands of the FNCC biology. The transversal competencies section contains references to both the creative and evaluating aspect of critical thinking – for instance, 'adopt…a multidisciplinary and creative way of working', 'evaluate their and other people's views…adopt an inquiry-based approach', 'analysing information critically' or 'express and justify views in a way that is characteristic for biology'. This is echoed in the general objectives by the mention of using and critically evaluating sources of biological information.

Mentioning of scientific inquiry is also present, though emphasis on research skills is not as prominent as is in FNCC physics and chemistry. The most explicit references to inquiry skills are in statements such as 'evaluate their and other people's views…adopt an inquiry-based approach', 'plan and carry out, independently or in groups, experimental work in various learning environments such as in the field, in laboratories, and in virtual environments'; and 'adopt an inquiry-based approach'.

The 'task of the subject' section contains reference to the development of technology skills through the planning and carrying out of experimental work in 'digital environments'. This, however, is the only reference to technology and does not explicitly state what 'digital environments' actually consist of, or what specific technological skills students should develop.

Effective communication and collaboration skills are well referenced throughout the 'transversal competences' and the 'general objectives' sections. Statements such as 'plan and carry out, independently or in groups, experimental work', 'present arguments…develop student's social and interaction skills', and 'express and justify different views' demonstrate the significant emphasis placed on communication skills in the FNCC biology curriculum.

Finally, throughout all areas of the FNCC biology there is emphasis on awareness of local and global problems and the impact of science. Statements such as 'assuming global responsibility as active members of society', 'applications and ecosystem services in relation to a sustainable future'; 'appreciation of how significant a clean and health environment with rich

biodiversity is for the holistic well-being of people' exemplify how cross-cutting this theme is throughout the FNCC biology curriculum.

Other Themes in the FNCC

The FNCC general objectives section for biology contains objectives that are very specific to science and much more centred on scientific knowledge. Examples of these are 'know the basic structures and functions of organisms' and 'understand the importance of evolution'. These do not appear in the DP themes as they are very content specific, and their primary purpose relates to acquisition of specific content areas rather than development of skills or techniques.

The FNCC also emphasises the importance of collaboration with outside agencies to give students a more real-world experience of biology: 'familiarise themselves with biological applications through visits or collaboration with higher educational institutions or workplaces at a local or international level' – something that is not as explicitly mentioned in the DP.

Finally, there is also a reference to students having awareness of the research occurring in their own country in relation to biology – 'understand that important research is carried out in Finland'. This is absent from the DP, somewhat expectedly due to the international nature of the programme.

Summary

The FNCC biology contains two different categories of objectives. Some are very broad and aim to interweave many different aspects of a students' learning experience into the teaching of biology, including social, ethical and environmental competences as well as understanding the importance of biology outside the discipline. Then, there are objectives that centre around very specific subject knowledge that appear to focus on knowledge acquisition rather than development or application of skills, which is different from the layout of aims and objectives in the DP.

This being said, the vast majority of learning outcome themes extracted from the DP are well evidenced in FNCC biology – the exception being the development of technological skills, which is only briefly alluded to. Other than that, FNCC biology features several references to collaborative working and communication, as well as an awareness of the 'bigger picture' which aligns closely with the DP's positioning of the study of biology as key to tackling big issues, such as the 'ever greater pressure on food supplies and on the habitats of other species'.[44]

Overall, thus, the FNCC biology aims to enable students to be able to contribute fully to society and have an appreciation of the importance of biology in many aspects of life – a very similar overall aim to that of the DP biology course.

[44] International Baccalaureate. (2023). *Biology guide*. p. 13.

4.4.2 Content

This section compares and contrasts the content of the DP and FNCC curricula falling within the category of biology. In order to support visual comparison at-a-glance, the biology content in the FNCC is presented below in a diagram that shows the key topics and sub-topics included.

Figure 9: FNCC biology content visualiser

Compulsory	BI1 Life and evolution (2 credits)	BI2 Basics of ecology (1 credit)	BI3 Human impact on the ecosystem (1 credit)
Optional	BI4 The cell and heredity (2 credits)	BI5 Human biology (2 credits)	BI6 Biotechnology and its applications (2 credits)

4.4.2.1 Structure

The Finnish biology curriculum is constructed using the National Core Curriculum for GUSE for guidance, though the document provides substantial leeway for schools to create their own syllabus.[45] In fact, all education providers prepare a local curriculum based on the FNCC, with each drawing up a plan to organise the national core curriculum into the school year,[46] which impacts the amount of time and emphasis placed on subject content. Notably, the local curriculum is prepared in a way that allows students to make their own decisions about the subjects they focus on.

The DP and FNCC biology have very different structures – the DP biology content is organised into four over-arching themes (A-D) each with four key areas, or levels, (1-4) within them. The FNCC biology consists of 'compulsory studies' and 'national optional studies' which are worth different numbers of credits towards a student's final 150 credits. Students studying biology must complete the compulsory studies, but can choose which, if any, of the national optional studies to complete. For the FNCC biology, there are three compulsory study units: BI1 is worth two credits, BI2 and BI3 are worth one credit each. The national optional studies (BI4, BI5 and BI6) are worth two credits each. Each of the compulsory and national optional studies contain a bullet point list of 'core contents', and some general guidance on how the content could be investigated. However, as discussed above, the precise delivery of the contents is decided by the education provider.

4.4.2.2 Content Alignment

The figure below represents a simplified summary of the FNCC's content alignment with the themes and levels in DP biology (SL and AHL).

[45] Finnish National Agency for Education. (2019). *NCC for General Upper Secondary Education.* p.13.
[46] Ibid.

Table 17: Summary of content alignment between DP biology and FNCC biology

DP biology themes and levels	SL presence in FNCC	AHL presence in FNCC
A Unity and diversity		
A1 Molecules		
A2 Cells		
A3 Organisms		
4 Ecosystems		
B Form and function		
1 Molecules		
2 Cells		
3 Organisms		
4 Ecosystems		N/A
C Interaction and interdependence		
1 Molecules		
2 Cells		
3 Organisms		
4 Ecosystems		N/A
D Continuity and change		
1 Molecules		
2 Cells		
3 Organisms		
4 Ecosystems		
Experimental programme		

Key:

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

The breadth of topics covered by the FNCC is somewhat similar to the breadth of the DP biology, but with substantial gaps in the coverage of certain topics. When it comes to DP SL content, the FNCC covers all the content in theme A. Unity and diversity, to a similar depth, apart from level A1. Molecules which is absent. The FNCC also covers the entirety of themes C. Interaction and interdependence and D. Continuity and change, although coverage of these areas is only partial. However, theme B. Form and function is mostly absent from the FNCC, as the latter does not go into detail of the biochemistry content contained within it; thus, FNCC biology does not (at least explicitly) cover the chemistry of B1.2 Proteins, B2.1 Membrane transport and has very little overlap with B2.2 Organelles and compartmentalisation.

As to AHL content, the FNCC has alignment with some topic areas within each main theme – i.e. cells and organisms within A. Unity and diversity and D. Continuity and change, as well as organisms within B. Form and function, and molecules and cells within C. Interaction and interdependence. However, this alignment is only partial as the depth of coverage of each topic is limited when compared to the DP HL. The DP's experimental programme is partially aligned with the FNCC biology curriculum. Within the FNCC task of the subject,[47] there is reference to characteristic features of biology being 'information acquisition based on observation and experiments, research-based practises', as well as the teaching and learning involving laboratory work. Within the general objectives for biology[48] students will plan and carry out investigations, either independently or in groups, and these could be done in the

[47] Finnish National Agency for Education. (2019). *NCC for General Upper Secondary Education*. p.282
[48] Ibid. p.284.

laboratory or virtually. Unlike physics and chemistry, there are no suggested practical experiments for each module. Although the FNCC emphasises the importance of carrying out practical work in biology, there is a greater focus on the planning and investigation side rather than the data analysis and evaluation aspects. There is also not enough detail in the documentation to determine the extent to which a written report of findings is created following experiments. This follows the style of the FNCC documentation, which provides guidance on which the local education establishments then build their curricula, allowing freedom of choice for the amount and type of practical work to be carried out.

As can be seen below, there are also a few content areas which are covered by FNCC biology but are absent from DP biology. The style of the FNCC makes it difficult to ascertain the level of detail to which these areas are covered. The sustainability aspect and protecting the environment is a factor in the DP; however, the FNCC is specific with regard to the examples and focus of this component, as the curriculum states: 'know methods for examining and following the state of the environment and for identifying environmental problems', 'are able to compare, analyse, and evaluate the impacts of human activity on ecosystems', 'know how to present, with justifications, solutions to environmental problems and recognise positive trends in the state of the environment'[49]. The DP is more general in its approach to this theme, mentioning 'protecting the environment' without the specific emphasis featured in the FNCC.

Table 18: FNCC biology content which is not covered in the DP

Significant FNCC content which is not included in DP biology*
• Secretion of metabolic waste • Utilisation of microbes in technology: gene transfer and modification techniques • Applications of biotechnology and their importance (DNA engineering and examination) • Sustainability and protecting the environment with specific examples and focus

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

Summary

While there are similarities between the content coverage of the FNCC and the DP, there is less alignment regarding depth, as many of the topics within the DP curriculum are absent from the FNCC. This is particularly the case for topics within the DP's B. Form and function, which are almost entirely absent from the FNCC biology syllabus.

However, these limitations in depth may be partially due to the FNCC's less prescriptive nature in regard to subject content. Notably, given that each education provider develops their own curriculum based on the FNCC, the fact that these sub-topics are not explicitly mentioned in the latter does not necessarily mean that they are altogether absent from the former.

4.4.3 Demand

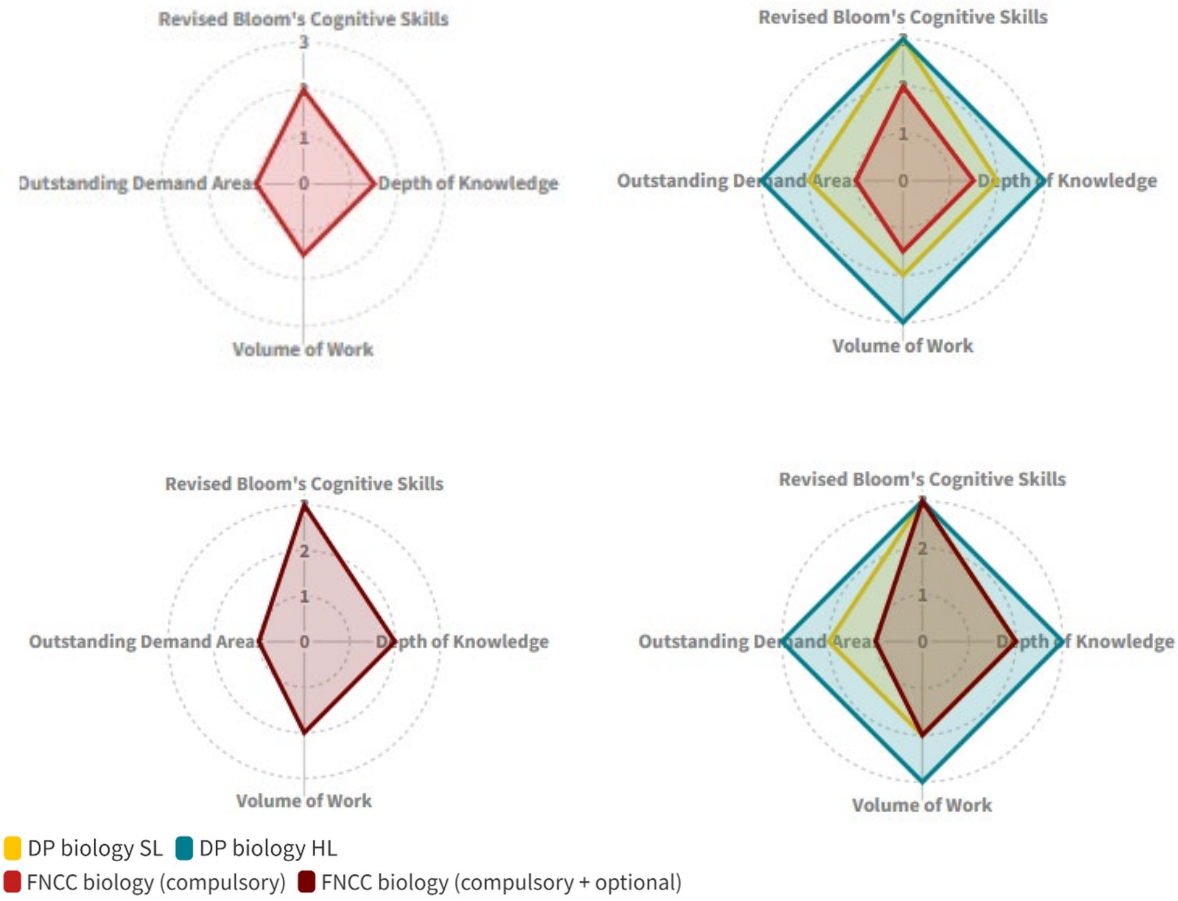
This section considers the alignment between the DP and FNCC biology curricula in terms of demand.

The DP and FNCC curricula were analysed using the same demand tool in order to create a demand profile for DP biology SL, DP biology HL, FNCC biology (compulsory), and FNCC

[49] Ibid. p. 288.

biology (compulsory and optional). These demand profiles are presented below in the form of radar diagrams, with the last diagram showing all profiles superimposed in one place, enabling immediate visual comparison.

Figure 10: Visual representations of subject demand



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**:
  - Both DP biology SL and HL received a score of 3.
  - Finland's compulsory biology was given a score of 2 for Bloom's due to the substantial focus of the subject's learning outcomes on application and analysis. Although references to higher order thinking skills such as evaluation, creation and problem solving are present, the opportunity to develop them within the limited time available for studying the compulsory modules impeded the award of a score of 3. For Finland's compulsory and optional biology combined, the score of 3 was given as there is greater emphasis on higher order thinking skills and interdependence within the students' learning.

- Regarding the score for **Depth of Knowledge**:
  - DP biology SL received a score of 2 and HL received a score of 3.

  - The score of 1.5 was judged for compulsory biology topics. This was reached due to the presence of research skills such as ‘formulate questions’ and ‘carry out experimental research’ as well as a considerable amount of problem solving within the curriculum. However, due to the FNCC being so open and adaptable to students’ learning, the lack of detail provided prevents this judgement from being increased, therefore a score of 1.5 was found to be appropriate. For compulsory and optional studies in FNCC biology, the score of 2 was awarded. As students in Finland are very much in control of which courses they study and how many, this affects the depth of knowledge they can obtain in each subject. In biology, however, the depth within the optional modules was limited; for example, students are restricted to focusing on the structure and function of eukaryotic cells, rather than also covering prokaryotic cells. Thus, even if students study both the compulsory courses and some of the optional courses, their experience of the subject will include some higher order thinking but not over extended periods of time, warranting a score of 2.

- Regarding the scores for **Volume of Work**:
  - DP biology SL received a score of 2 and HL received a score of 3.
  - The score of 1.5 was given for FNCC compulsory biology due to the moderate number of themes and amount of time on issues beyond basic conceptual depth. For FNCC compulsory and optional biology courses combined, a score of 2 was given based on the increased breadth of the content covered in some of the optional courses, and the less generous time allocation per topic.

- Regarding the scores for **Outstanding Areas of Subject Demand**:
  - DP biology SL received a score of 2 and HL received a score of 3.
  - For both FNCC compulsory biology and FNCC compulsory and optional biology combined, a score of 1 was given due to the emphasis on research and experimental skills. The latter provide opportunities for students’ learning and understanding to be stretched appropriately for their individual strengths, amounting to an area of stretch.

4.5 Singapore

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).[50] This report focuses on the Singaporean GCE A Level (SGA) curriculum taught at junior colleges (JCs) and the Millenia Institute (MI), leading to the GCE A Level examination and qualification[51] and represents the most common route to higher education.

The SGA curriculum is taught over two to three years (two years in JCs and three in MI) and organises courses 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.[52]

Life skills are not assessed in the GCE A Level examinations.

Each content-based and 'knowledge skills' subject will be described by a level. The three possible levels of study are the following:[53]

- 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.[54] The syllabi are designed such that students study **either** H1 or H2, they do not study both. In contrast, H2 is a requirement to study H3, as 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 – e.g. the General Paper is only offered as H1.

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

[50] MOE, Singapore. (2022). *Post-secondary Education Booklet*. Available from: post-secondary-education-booklet-2022.ashx (moe.gov.sg)
[51] SEAB. (2022). *GCE A Level*. Available from: www.seab.gov.sg/home/examinations/gce-A Level
[52] MOE, Singapore. (2022). *A Level curriculum and subject syllabuses.* Available from: www.moe.gov.sg/post-secondary/A Level-curriculum-and-subject-syllabuses
[53] Ibid.
[54] MOE, Singapore. (2015). *The 'A' Level Experience. Levels of Study.* Available from: Ministry of Education Singapore: New 'A' Level Curriculum 2006 (archive.org)

- 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.[55]

In practice, this typically means that students take:

- at least four content-based subjects, usually:
  - three H2 content-based subjects
  - one H1 content-based subject
- H1 Mother Tongue Language (MTL) (or MT syllabus B in some circumstances[56])
- H1 General Paper, or H2 Knowledge and Inquiry in lieu – the latter counting as a fourth H2 subject.[57]
- H1 Project Work.

It is required that at least one of the four content-based subjects is from a contrasting discipline.

Hence, the SGA does not require students to study biology, but for those wishing to do so, the following courses are offered and have been used in the analysis:

SGA H1 biology[58]

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[59]

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.

[55] SEAB. (2022). *2022 Singapore-Cambridge GCE A Level Examinations - Registration Information for School Candidates.* Available from: 2022 Instructions For School Candidates (seab.gov.sg)
[56] 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.
[57] SEAB. (2022). *2022 Singapore-Cambridge GCE A Level Examinations - Registration Information for School Candidates.*
[58] MOE, Singapore. (2020). *Biology Syllabus. Pre-University Higher 1. Syllabus 8876.* Available from: pre-university-h1-biology.ashx (moe.gov.sg)
[59] MOE, Singapore. (2019). *Biology Syllabus. Pre-University Higher 2. Syllabus 9744.* Available from: pre university_h2_biology_syllabus.ashx (moe.gov.sg)

SGA H3 biology[60]

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.

4.5.1 Learning Outcomes

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

The learning outcome themes for biology 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 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 biology curricula.

[60] MOE, Singapore. (2021). *Biology Syllabus. Pre-University Higher 3. Syllabus 9816.* Available from: 2021-preu-h3-biology.ashx (moe.gov.sg)

Table 19: 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 […] economic, 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.

4.5.2 Content

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 biology content in the SGA is presented below in a diagram that shows the key topics and sub-topics included.

Figure 11: 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.[61]					

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

4.5.2.1 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'.[62] The H1 syllabus is focused on equipping students with the skills they need to make 'informed decisions based on sound scientific knowledge and principles'[63] 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'.[64] 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'.[65] 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 subject areas in which there are several 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 levels within each theme, 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'.[66]

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 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.

[62] MOE, Singapore. (2020). *Biology syllabus Pre-University Higher 1.* p.1.
[63] Ibid.
[64] MOE, Singapore. (2019). *Biology syllabus Pre-University Higher 2.* p.1.
[65] MOE, Singapore. (2021). *Biology syllabus Pre-University Higher 3.* p.3.
[66] Ibid. p.7.

4.5.2.2 Content Alignment

To complement the analysis, the table 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.

Table 20: Summary of the content alignment the SGA biology H1, H2 and H3 has with the main themes of the DP biology

DP biology themes and levels	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						
A1 Molecules						
A2 Cells						
A3 Organisms						
A4 Ecosystems						
B Form and function						
B1 Molecules						
B2 Cells						
B3 Organisms						
B4 Ecosystems		N/A		N/A		N/A
C Interaction and interdependence						
C1 Molecules						
C2 Cells						
C3 Organisms						
C4 Ecosystems		N/A		N/A		N/A
D Continuity and change						
D1 Molecules						
D2 Cells						
D3 Organisms						
D4 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 level in the SGA.		*Partial presence of this level in the SGA.*		*Little or no presence of this level in the SGA.*	N/A	*This level does not exist.*

Table 21: SGA biology content which is not covered in the DP

Significant SGA 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, themes A. Unity and diversity and C. Interaction and interdependence have only one level that aligns with the Singaporean curriculum, and the organisms and ecosystems levels are absent from theme B. Form and function.

The H1 curriculum has the highest alignment with theme D. Continuity and change, with all SL content being covered, even if generally partially. Some AHL content in this theme is also partially covered, though the depth is not comparable, and coverage of AHL content in all other themes 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'.[67] 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.[68] 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. While theme A. Unity and diversity is still not covered to a great extent, themes B. Form and function, C. Interaction and interdependence, 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 levels within theme D were partially covered, in H2 there is strong alignment with the AHL content on molecules within theme C. Interaction and interdependence, and a number of additional partial alignments with AHL content in other levels, namely A2. Cells, B1. Molecules, B2. Cells, and C2. Cells.

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. H2 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

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

'Although successful vaccination programmes in Singapore have kept [tuberculosis] under control, there have been new cases appearing in the population'.[69] 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 themes 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 B1. Molecules. There are a number of gaps where there is no real alignment between the DP and H3, particularly in the theme A. Unity and diversity. The focus of 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

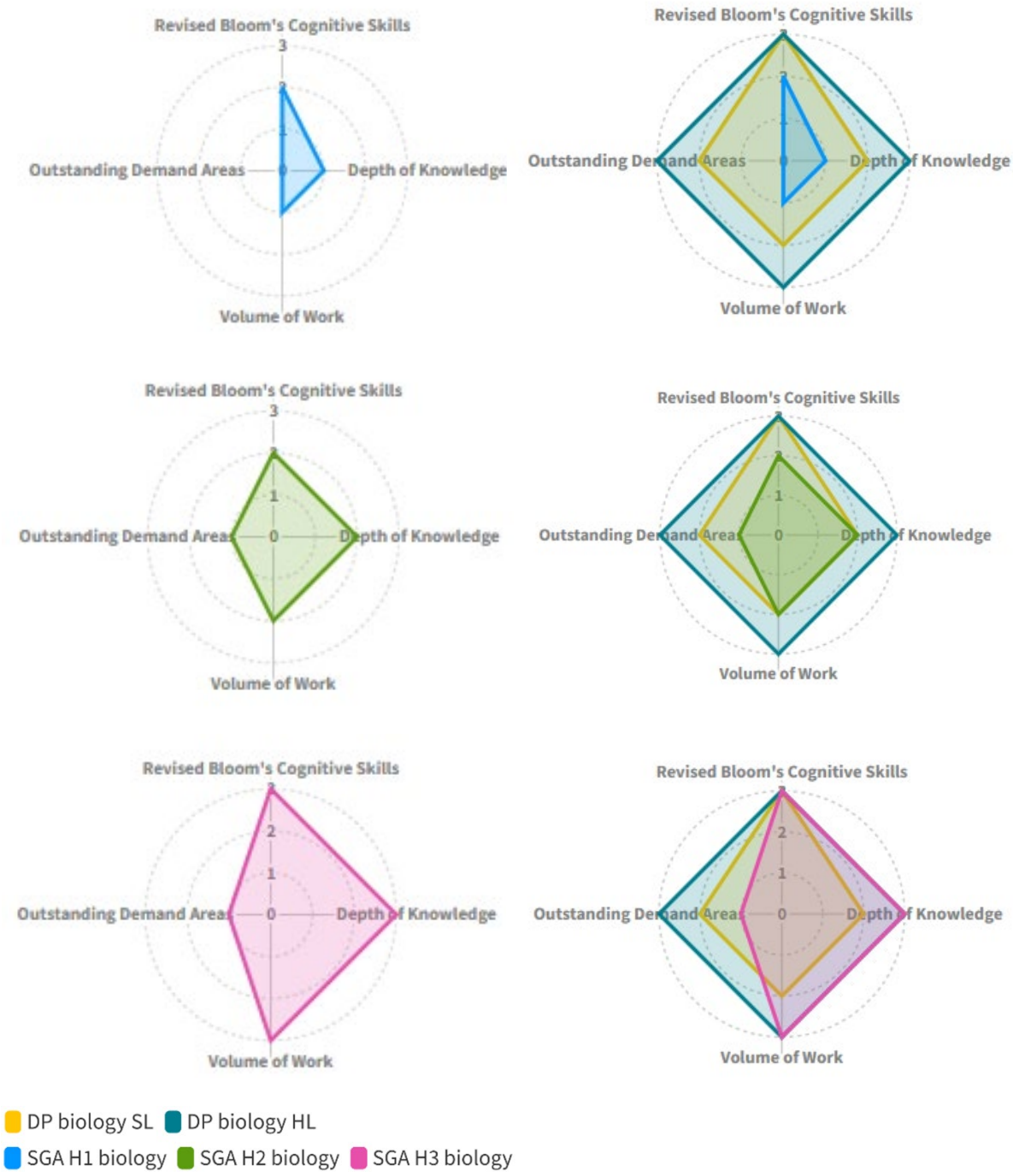
As the SGA curriculum progresses from H1 to H3, the alignment with the DP in both breadth and depth increases with the level – being lowest at H1 and highest at H3. The SL content in theme D. Continuity and change is well-covered in each syllabus, but theme A. Unity and diversity is almost entirely absent from all. A large part of theme 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'[70] 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.[71]

4.5.3 Demand

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.

[69] MOE, Singapore. (2019). *Biology Syllabus Pre-University Higher 2.* p.33
[70] 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 12: Visual representations of subject demand



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**:
  - Both DP biology SL and HL received a score of 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 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 received a score of 2 and HL received a score of 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 received a score of 2 and HL received a score of 3.
  - 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**:
  - DP biology SL received a score of 2 and HL received 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.

4.6 South Korea

The school system in South Korea is overseen by the Ministry of Education (MOE – 교육부).[72] It is divided into primary school (grades 1-6, typically from ages 6 to 12), middle school or lower secondary school (grades 7-9, typically from ages 12 to 15), and high school or upper secondary education (grades 10-12, typically from ages 15-18).[73]

High school education is offered by several different types of schools, including:

- General high schools
- Vocational high schools
- Special purpose high schools
- Autonomous high schools.[74]

The focus of this report is on the curriculum offered by general high schools and leading to the High School Certificate of Graduation (KHSCG); other routes will not be discussed in depth.

The KHSCG curriculum spans the three years of South Korea's upper secondary education. Beginning in grade 10, students select courses which earn them units towards the KHSCG, which is intended to grant access to higher education upon successful completion. The high school curriculum is comprised of common courses, electives, and what is referred to as 'creative experiential activities' (CEA), consisting of 'discretionary activities, club activities, community services, and career-related activities'.[75]

Common courses are mandatory courses studied by all students. All students completing a KHSCG must study the common courses in: Korean Language, Mathematics, English, Korean History, Integrated Social Studies, Integrated Science, Scientific Investigation. Students must also study courses in Physical Education, Arts, and Life/Liberal Arts (i.e. Technology, Home Economics, Second Foreign Language, Classical Chinese or Liberal Arts).

Electives are non-compulsory courses selected by students according to their aptitudes and career plans. They are divided into general electives and career-related electives.

To successfully complete the KHSCG, students must study a minimum of 204 units (i.e. 2,890 hours) over the course of three years, of which:

- 180 units (i.e. 2,550 hours) are typically earned through successful completion of common courses and elective courses and/or specialised courses combined. Notably, all units studied from the 'Foundation' subject group may not exceed the 50% of the total number of units in the programme.[76]
- At least 24 units (i.e. 340 hours) must be earned through the completion of CEA.

[72] MOE, Republic of Korea. (2018). *Education in Korea*. Available from: http://english.moe.go.kr/boardCnts/viewRenewal.do?boardID=282&boardSeq=80324&lev=0&searchType=null&statusYN=W&page=1&s=english&m=0502&opType=N
[73] Ibid.
[74] MOE, Republic of Korea. (2022). *Secondary Education.* Available from: english.moe.go.kr/sub/infoRenewal.do?m=0303&page=0303&s=english
[75] Ibid.
[76] Ibid.

Each unit in the KHSCG is equivalent to 17 lessons of 50 minutes each.[77] The following table provides a summary of the unit allocation per subject cluster:

Table 22: Unit requirements of the KHSCG

Subject areas	**Subject clusters**	**Minimum required units per subject cluster** (units from the common courses)	**Electives and/or specialised courses**
Foundation	Korean Language	**10 units** Korean Language (8 units)	Selected subjects from general electives, career-related electives, or specialised subjects*
	Mathematics	**10 units** Mathematics (8 units)	
	English	**10 units** English (8 units)	
	Korean History	**6 units** Korean history (6 units)	
Inquiry	Social Studies (including History/ Moral Education)	**10 units** Integrated social studies (8 units)	
	Science	**12 units** Integrated science (8 units) Scientific investigation (2 units)	
Physical Education/ Arts	Physical Education	**10 units**	
	Arts	**10 units**	
Life/Liberal Arts	Life/Liberal Arts (i.e. Technology/ Home Economics/ Second Foreign Language/ Classical Chinese/Liberal Arts)	**16 units**	
Sub-total		**94 units**	**86 units**
Creative experiential activities (CEA)			
Discretionary activities, club activities, community services, and career-related activities			**24 units**
Total		**204**	
NB: Units assigned to common courses can be reduced up to 2 units, except for Korean History, where the full 6 units are required.[78]			

As seen in the table above, students are required to study the 'Integrated Science' and 'Scientific Investigation' courses as part of the curriculum, though the study of biology is optional.

The below subjects were used in the analysis.

[77] MOE, Republic of Korea. (2015). *The National Curriculum for the Primary and Secondary Schools*. p. 20
[78] Ibid. p.19.

KHSCG Integrated Science[79]

Integrated Science is taken by all students in the KHSCG, and has, therefore, been considered in this report as complementary to other science subjects. It has a strong emphasis on scientific inquiry and problem-solving skills through the study of various aspects of physics, chemistry and biology. Earth and space, the characteristics of matter, life and the environment make up some of the topics within the curriculum. Integrated Science also contains a lot of investigation and experiments through which students can gather results and apply their understanding. Collecting data, analysing and evaluating this data and then communicating it to others is a large part of this subject.

KHSCG Scientific Investigation[80]

As well as Integrated Science, students in the first year of high school will also take the common course of Scientific Investigation. This subject looks at past experiments and discoveries, research methods and ethics, and the process of scientific inquiry. Students' interest and curiosity will be developed as they learn how science is linked to sport, art and culture, technology, and the development of products. During this subject, students will plan and conduct their own scientific inquiries, inspired by problems that they themselves have discovered.

KHSCG biology[81]

The biology subject consists of Biology I and Biology II and aims to provide essential understanding of what life is, the human body and diversity within ecosystems. It provides students with the ability to research, think and solve problems scientifically. Logical reasoning and using evidence to formulate an argument are strong themes within Biology I so that students become better communicators and lifelong learners. Biology II contains more content and goes to a slightly deeper level, but still emphasises the importance of using investigative skills and evidence to solve scientific problems.

4.6.1 Learning Outcomes

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

The learning outcome themes for biology were extracted from the aims and assessment objectives of the DP sciences subject group, hence the themes are the same for biology, chemistry and physics. For the purposes of mapping and comparisons with the DP, the learning outcomes for KHSCG biology were extracted from the 'character' and 'objectives' sections of the Biology I and Biology II subjects.

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 KHSCG biology curricula.

[79] MOE, Republic of Korea. (2015). *Science Curriculum.*
[80] Ibid.
[81] Ibid.

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

Themes extracted from the learning outcomes of the DP sciences subject group	Presence in the KHSCG	
1. Conceptual understanding and making connections		Present in both the 'character' and 'objectives' sections. KHSCG discusses the links between multiple aspects of its curriculum and mentions the comprehensive nature of biology around the world.
2. Use and application of knowledge, methods, tools, and techniques that characterise science		Present in both the 'character' section. Students are expected to understand that scientific knowledge is based on logical reasoning and discovery through observation and exploration.
3. Creativity and critical thinking (problem-solving, analysis, evaluation, synthesis)		Present in both the 'objectives' and 'character' sections. There is reference throughout these sections to problem solving and critical consideration.
4. Skills for scientific inquiry		Present in both the 'character' and 'objectives' sections which discuss the collection of data, research activities and selecting and organising data.
5. Development of technological skills		Present in both the 'character' and 'objectives' sections. Computers, the use of various media and information technology is referred to throughout the KHSCG outcomes.
6. Effective collaboration and communication		Present in both the 'character' and 'objectives' sections through the mention of students' ability to advocate their own ideas, understand others and use various forms of communication to express scientific information.
7. Awareness of global and local problems and the environmental, ethical, cultural, and social impact of science		Present in both the 'character' and 'objectives' sections. The KHSCG encourage students to become lifelong learners and pay attention to social issues of science and technology.

Key:

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

Presence of the DP's Learning Outcome Themes

As can be seen from the table above, all learning outcome themes extracted from the DP are present in one or more areas of the KHSCG curriculum. Conceptual understanding is evident in statements such as 'explore life phenomena and understand the core concepts of biology' in the objectives for Biology I and Biology II, or 'thinking and using scientific facts, principles, concepts' in the character section of Biology II. Making connections between subjects, too, is present in statements such as 'recognise the mutual relationship between biology, technology and society, and develop knowledge as a democratic citizen based on this' and the fact that the 'content composition of 'Biology II' is closely related to the concepts of biology contained in 'Integrated Science', 'Scientific Investigation and 'Biology I', implying linkages within the sciences and biology subjects.

The use and application of methods, tools and techniques that characterise science is evident throughout all areas, in statements such as 'ability to collect, interpret, and evaluate evidence through various methods', 'scientific world view and view of nature, scientific knowledge and methods, the ability to make reasonable and logical inferences based on scientific evidence

and theories', 'enjoy learning scientific knowledge and inquiry methods', and 'evaluate evidence through various methods'. Similar statements are dotted throughout the curriculum, illustrating that this theme is of great focus in the KHSCG curriculum.

Within the creativity and critical thinking theme, problem solving is referenced throughout the curriculum and is reflected in statements such as 'learning centred on multiple inquiries are used to cultivate scientific thinking ability, scientific inquiry ability, scientific problem solving ability', or 'solve scientific problems and obtain new scientific knowledge or construct meaning'. The 'creativity' aspect is also prominent in the curriculum, in statements such as 'understanding life phenomena…so as to creatively solve various problems in life', and 'solving individual and social problems scientifically and creatively'.

The application of skills to carry out insightful and ethical investigations is also strongly evident throughout all areas of the curriculum. Statements such as 'collect, interpret, and evaluate evidence through various methods such as experiments, investigations, and discussions in order to solve scientific problems and obtain new scientific knowledge or construct meaning', 'scientific inquiry skills and knowledge, and scientific thinking' all demonstrate the prominence of this theme in the KHSCG curriculum.

Technology is another major focus throughout the KHSCG curriculum and is repeatedly referred to in all subjects, in statements such as 'recognise the mutual relationship between biology, technology and society'; 'understand and express scientific and technical information through various media such as computers and audio-visual equipment'.

Communication and collaboration, too, are repeatedly mentioned in both the character and the objectives sections of the Biology I and Biology II curriculum. Examples of instances where this is explicitly mentioned include: 'scientific communication ability, scientific participation', 'the ability to collect, interpret, and evaluate evidence through…discussions' and 'the ability to advocate one's own ideas, understand others' ideas, and adjust them in order to share and develop the process and results of solving scientific problems within the community'. Various means of communication are even explicitly mentioned: 'various forms of communication such as speech, words, pictures and symbols, the ability to understand and express scientific and technical information through various media'.

Finally, the awareness of local and global problems is also strongly evident throughout all areas of the curriculum and an understanding of the impact of science for society is clearly a priority concept for students to grasp. This is nicely illustrated by the following quotes: 'the ability to keep learning as a member of the community in order to act reasonably and responsibly, pay attention to social issues of science and technology, participate in the decision-making process, and adapt to new scientific and technological environments'; 'recognise the mutual relationship between biology, technology and society, and develop knowledge as a democratic citizen'.

Other Themes in the KHSCG

There are no main learning outcomes in the KHSCG curriculum that are not present or related to the DP themes.

Summary

There is a strong level of alignment between the learning outcomes of the DP biology and those of KHSCG biology, with all themes extracted from the DP being strongly evidenced in the KSHCG. The Korean biology curriculum aims to create well-rounded, curious students who have an appreciation for science as a whole and its place in the world. This aligns well with the DP's intentions of developing learners who are 'curious…and show enthusiasm about the world around them',[82] as well as students who care for the environment and act to 'improve the lives of others'.[83]

4.6.2 Content

This section compares and contrasts the content of the DP and KHSCG curricula falling within the category of biology. In order to support visual comparison at-a-glance, the biology content in the KHSCG is presented below in a diagram that shows the key topics and sub-topics included.

[82] International Baccalaureate. (2023). *Biology guide*. p. 12
[83] International Baccalaureate. (2023). *Biology guide*. p. 13

Figure 13: KHSCG science/biology content visualiser

Common Subject	Integrated Science	Substance and regularity	Regularity and Combination of Substances	Components of Environment	
		System and interaction	Dynamic systems	Earth systems	Life systems
		Change and diversity	Chemical changes	Biodiversity and sustainability	
		Environment and division energy	Ecosystem and environment	Development of renewable energy	
	Scientific Investigation	Scientific experiments in history	Nature of science	Research methods	
		Scientific experiments in daily life	Approach to scientific experiments	Scientific inquiry process	
		High-tech scientific experiments	Application of science		
General electives	Biology I	Biology and human life	Characteristics and the development process of biology		
		Structure and energy of living organisms	Structure and function of animals		
		Homeostasis and bodily control	Stimulation and reaction	Defense mechanisms	
		Genetic inheritance	Reproduction	Heredity	Evolution and diversity
		Environment and ecosystems	Ecosystem and interactions		
Career-related electives	Biology II	Biology and human life	Characteristics and the development process of biology	Biotechnology	
		Structure and energy of living organisms	Chemical basis of life	Units of life	Photosynthesis and respiration
		Genetic inheritance	Reproduction	Heredity	Evolution and diversity

4.6.2.1 Structure

While the DP biology is taught over two years, the biology curriculum in the KHSCG is designed to be completed in three years. The high school national curriculum is referred to as 'electives-centred' and runs from the first grade to the third grade[84]. Science is a 'common subject' in the curriculum; hence all students must take the common courses of 'Integrated Science' and 'Scientific Investigation. The number of required science units is 12, with the common courses making up 10 of these units. Following the common courses, students are offered electives to choose from. The elective courses are divided into two categories: general electives (Physics I, Chemistry I, Biology I and Earth Science I) and career-related electives (Physics II, Chemistry II, Biology II, Earth Science II, Science and History, Life and Science, and Convergence Science). For reference, The KHSCG curriculum states that schools should 'guide all students to take more than three career-related elective courses',[85] and that they should organise a school curriculum 'appropriate for their circumstances and based on national guidelines'.[86]

As to the structure of the biology curriculum in particular, the DP splits it into four over-arching themes – i.e. A. Unity and diversity; B. Form and function; C. Interaction and interdependence; D. Continuity and change – with each covering four levels, namely 1. Molecules, 2. Cells, 3. Organisms and 4. Ecosystems. Somewhat differently, the KHSCG splits the curricula of its biology electives, Biology I and Biology II into five and three overarching themes, respectively. These include 'Biology and human life', 'Structure and energy of living organisms', 'Genetic inheritance' for both subjects, and the additional 'Homeostasis and bodily control' and 'Environment and ecosystems' for Biology I. As can be seen in the figure above, each of these overarching themes covers between one and three large topics.

4.6.2.2 Content Alignment

The figure below represents a simplified summary of the KHSCG's content alignment with the themes and levels within DP biology (SL and AHL).

[84] MOE, Republic of Korea. (2015). *The National Curriculum for the Primary and Secondary Schools.* p.7
[85] Ibid. p.44.
[86] Ibid. p.50.

Table 24: Summary of content alignment between DP biology and KHSCG biology

DP biology themes and levels	SL presence in KHSCG	AHL presence in KHSCG
A Unity and diversity		
A1 Molecules		
A2 Cells		
A3 Organisms		
A4 Ecosystems		
B Form and function		
B1 Molecules		
B2 Cells		
B3 Organisms		
B4 Ecosystems		N/A
C Interaction and interdependence		
C1 Molecules		
C2 Cells		
C3 Organisms		
C4 Ecosystems		N/A
D Continuity and change		
D1 Molecules		
D2 Cells		
D3 Organisms		
D4 Ecosystems		
Experimental programme	Within the 'Scientific Investigation' course	

Key:

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

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

As shown in the figure above, the biology coverage in the KHSCG curriculum is similar to that of the DP biology. Most SL content is covered at least partially, with the exception of topics B3.1 Gas exchange and B3.2 Transport, and most content from B4.1 Adaptation to environment and B4.2 Ecological niches. Otherwise, the remaining topic areas within B. Form and function are covered in similar depth as the DP SL. The KHSCG aligns particularly strongly with the SL content in C. Interaction and interdependence and A. Unity and diversity.

Alignment with the DP is slightly lower for AHL content, however; the breadth of AHL content covered is similar, but there are only partial alignments with most levels. While there is strong alignment with B1. Molecules and C1. Molecules, the remaining AHL content is not covered by the KHSCG in comparable depth, with two levels completely absent from the KHSCG curriculum. The experimental programme of the DP is partially covered within Biology I and Biology II through references to experimental research and project work. In addition to this, all students complete the 'Scientific Investigation' common course which involves students carrying out an investigation from a topic of their choice; planning, obtaining and analysing results and then completing a small write-up of this. Therefore, the DP's experimental programme is fully aligned with the KHSCG.

Notably, the KHSCG also devotes attention to some topics and areas which are absent or receive limited attention in the DP (see table below). These include: biotechnology and its

application to medical and food industries; recombinant DNA technology, nuclear replacement and cell fusion; the use of stem cells, monoclonal antibodies and gene therapy; ecological, ethical, legal and social issues with biotechnology; and an overall emphasis on the importance of biology in 'everyday life' or 'real life'. For instance, KHSCG Biology I covers the investigation of 'the positive and negative effects of living modified organisms on human life and ecosystems', a topic that does not receive the same level of attention in the DP.

Table 25: KHSCG biology content which is not covered in the DP

Significant KHSCG content which is not included in DP biology*
• Biotechnology and its importance in the medical and food industries • Recombinant DNA technology, nuclear replacement and cell fusion • Use of stem cells and gene therapy • Ecological, ethical, legal and social issues with biotechnology • Learning from science throughout history • Integration of science in everyday life through decisions regarding food, make-up, architecture, transport and sports

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

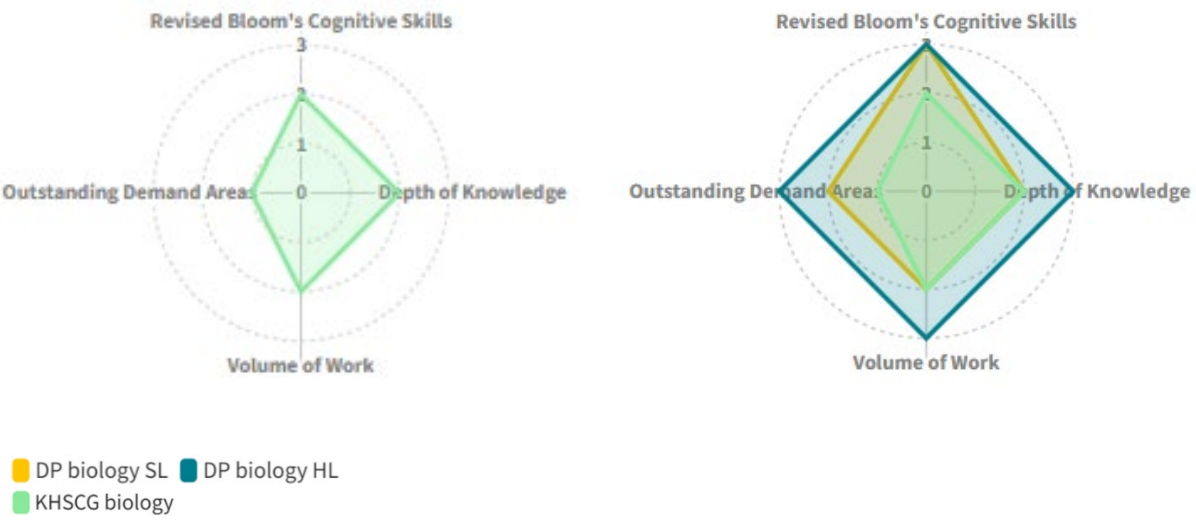
Summary

Overall, there is moderate to high alignment between KHSCG and DP biology, with higher alignment with SL content and lower alignment with AHL content. While there is a significant proportion of shared topic coverage between the KHSCG biology and SL, the breadth and depth of the HL coverage exceeds that of the Korean curriculum in a number of areas. Conversely, there are also some areas which receive exclusive or greater attention in the KHSCG, such as coverage of recombinant DNA technology, nuclear replacement and cell fusion and the general focus on ecological, ethical, legal and social issues of biotechnology, further reducing the level of alignment between the two curricula.

4.6.3 Demand

The DP and KHSCG curricula were analysed using the same demand tool in order to create a demand profile for DP biology SL, DP biology HL, and KHSCG biology. These demand profiles are presented below in the form of radar diagrams, with the last diagram showing all profiles superimposed in one place, enabling immediate visual comparison.

Figure 14: Visual representations of subject demand



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**:
  - Both DP biology SL and HL received a score of 3.
  - The score of 2 was given to the KHSCG biology curriculum due to the presence of higher order thinking skills in the learning outcomes, such as 'problem solve, analyse and develop original ideas'. However, the focus is not predominantly on these aspects, hence the judgement of 2.

- Regarding the score for **Depth of Knowledge**:
  - DP biology SL received a score of 2 and HL received a score of 3.
  - The KHSCG biology's received a score of 2 due to the strong emphasis on inquiry, and the linking across multiple topics and subjects. The threshold for a score of 3 was judged not to be met as the inquiry and linking processes do not appear to be complexly drawn out over a long period of time.

- Regarding the scores for **Volume of Work**:
  - DP biology SL received a score of 2 and HL received a score of 3.
  - A score of 2 was given to KHSCG biology as the amount of content covered and time allocation per theme are relatively standard, and most themes are covered in considerable detail, going beyond basic conceptual depth.

- Regarding the scores for **Outstanding Areas of Subject Demand**:
  - DP biology SL received a score of 2 and HL received a score of 3.
  - No specific subject content areas within KHSCG biology were regarded as outstanding in terms of demand. However, the consistent theme of scientific inquiry and the linking of multiple concepts provides significant opportunity for stretching students' understanding, hence the score of 1.

4.7 United States

The NGSS are a set of standards, developed in 2013, outlining the scientific and engineering practices, crosscutting concepts, and core ideas within science that all K-12 students' education should be tailored around in applicable states.[87] They were developed with the intention of aligning current scientific curriculum demands with more contemporary understandings of science, and modern understandings of best teaching practice.[88]

The NGSS were developed in a collaborative, state-led process by science supervisors from 26 states, consulting teachers, scientists, and education workers, who drafted the standards based on the National Research Council's document 'A Framework for K-12 Science Education'.[89] Overall, the NGSS promote 'student-centred' learning that encourages collaboration, communication, and problem solving.[90] The standards propose five innovations for teaching, designed to enhance the quality of content and learning when delivering science education:

Table 26: Five innovations for teaching developed within the NGSS.[91]

Innovations for teaching	
Three-dimensional learning	There are three equally important, distinct dimensions to learning science included in the NGSS: Scientific and Engineering Practices, Crosscutting Concepts, and Disciplinary Core Ideas. The NGSS connect all three dimensions. To prepare students for success in college and 21st century careers, the NGSS also connect scientific principles to real-world situations, allowing for more engaging and relevant instruction to explore complicated topics.
All three dimensions build coherent learning progressions	The NGSS provide students with continued opportunities to engage in and develop a deeper understanding of each of the three dimensions of science. Building on the knowledge and skills gained from each grade – from elementary through high school – students have multiple opportunities to revisit and expand their understanding of all three dimensions by the end of high school.
Students engage with phenomena and design solutions	In instructional systems aligned to the NGSS, the goal of instruction is for students to be able to explain real-world phenomena and to design solutions using their understanding of the Disciplinary Core Ideas. Students can achieve this goal by engaging in the Science and Engineering Practices and applying the Crosscutting Concepts.
Engineering and the Nature of Science is integrated into science	Some unique aspects of engineering (e.g., identifying problems) are incorporated throughout the NGSS. In addition, unique aspects of the nature of science (e.g. how theories are developed) are also included throughout the NGSS as practices and crosscutting concepts.
Science is connected to math and literacy	The NGSS not only provide for coherence in science instruction and learning but the standards also connect science with mathematics and English Language Arts. This meaningful and substantive overlapping of skills and knowledge affords all students equitable access to the learning standards.

[87] NGSS Lead States. (2013). *Next Generation Science Standards: For States, By States. Developing the Standards.* https://www.nextgenscience.org/developing-standards/developing-standards
[88] NGSS Lead States. (2013). *Next Generation Science Standards: For States, By States. Factsheet.* https://www.nextgenscience.org/sites/default/files/resource/files/NGSSFactSheet2016revised.pdf
[89] National Research Council. (2012). *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. Available from: https://doi.org/10.17226/13165
[90] NGSS Lead States. (2013). *Next Generation Science Standards: For States, By States. Factsheet.*
[91] Ibid.

As can be seen above, they prioritise the development of students who are prepared to enter university and the 21st-century workforce. They do so particularly by emphasising linkages and connections between the scientific disciplines taught and the real world, building students' ability to engage with the latter and design solutions for real-world situations.

Notably, the standards do not dictate teaching methods or curriculum design, but rather set out goals upon which teachers are to devise their curriculum and lesson plans, allowing for flexibility and tailored delivery. The implementation of the standards is decided at state and local levels, allowing for flexibility and different approaches of their implementation alongside any other state-specific goals.[92]

In this study, the NGSS Life Sciences standards were used as the comparison point against the DP biology.

NGSS Life Sciences[93,94]
The NGSS high school standards apply from grades 9 to 12 and are split into Physical Sciences (PS), Life Sciences (LS), Earth and Spaces Sciences, and Engineering. LS cover topics relating to biology, including a number of those covered in the DP biology. As in the NGSS PS, the high school LS standards build upon the concepts taught and included in the middle school standards, so there is a natural progression from grade 8, the final year of middle school and high school where the content goes into greater depth and allows for further cross cutting themes to be explored across topic areas in science. The LS comprise of five main topic areas including structure and function, inheritance and variation of traits, matter and energy in organisms and ecosystems, interdependent relationships in ecosystems, and natural selection and evolution.

4.7.1 Learning Outcomes

The learning outcome themes for biology were taken from the aims and assessment objectives of the DP sciences subject group, hence the themes are the same for physics, chemistry, and biology. The NGSS for grades 9-12 are made up of performance expectations which were developed using three elements – science and engineering practices, disciplinary core ideas, and cross-cutting concepts. For the analysis of learning outcomes, the science and engineering practices are the most relevant; however, the cross-cutting concepts and performance expectations were also reviewed to add context. It is important to note that the NGSS performance expectations used in the analysis apply across all grades 9-12, rather than individual years of study.

The following table demonstrates the learning outcome themes that were extracted from the DP sciences subject group and indicates if and where they were judged to have presence within the learning outcomes of the NGSS LS.

[92] Ibid.
[93] NGSS Lead States. (2013). *Next Generation Science Standards: For States, By States. Understanding the Standards.* Available from: Understanding the Standards | Next Generation Science Standards (nextgenscience.org)
[94] NGSS Lead States. (2013). *Read the standards.* Available from: Read the Standards | Next Generation Science Standards (nextgenscience.org)

Table 27: Presence of the DP sciences learning outcome themes in the NGSS LS.

Themes extracted from the learning outcomes of the DP sciences subject group	Presence in the NGSS	
1. Conceptual understanding and making connections		Not present. No explicit reference to developing conceptual understanding or making connections.
2. Use and application of knowledge, methods, tools, and techniques that characterise science		Present. The science and engineering practices imply that students will have the knowledge and ability to apply it in various ways. Furthermore, some performance expectations explicitly refer to application of knowledge.
3. Creativity and critical thinking (problem-solving, analysis, evaluation, and synthesis)		Present. This is a strong theme of the science and engineering practices.
4. Skills for scientific investigation		Present. This is a strong theme of the science and engineering practices.
5. Development of technological skills		Present. The science and engineering practices frequently refer to using technology. Furthermore, how science and technology influence each other, society and the environment is a theme present in the NGSS.
6. Effective collaboration and communication		Present. Collaboration is referred to in the context of carrying out investigations. The science and engineering practices also expect that students communicate in various formats.
7. Awareness of global and local problems and the environmental, ethical, cultural, and social impact of science		Somewhat present. In the science and engineering practices, the impact of science is considered in context of carrying out investigations, and solving real-world problems is also stated. Also, how science, technology, society and the environment relate to one another is a theme in the NGSS, however only a limited number of performance expectations include this element.

Key:

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

Presence of the DP's Learning Outcome Themes

The demonstration of understanding and application as a theme is well reflected across the NGSS topic areas. Although the NGSS performance expectations are predominantly skills-focused, it is clear that students would need to acquire significant fundamental knowledge and understanding of the key facts and underpinning theories and concepts in order to acquire the stated competencies. This is evident from the introductory statement of each performance expectation 'students who demonstrate understanding can:', implying that developing an understanding is a precursor to the application of knowledge in practice. The NGSS 'disciplinary core ideas' include the key content students are expected to understand. For example, in the topic on forces and interactions, core disciplinary ideas include forces and motion, types of interactions and definitions of energy. Furthermore, a large proportion of the NGSS performance expectations involve applying knowledge across a range of different contexts and topic areas in the PS. Some make direct reference to 'apply', whereas others use other command words which similarly invoke the application of knowledge and skills.

However, there is no explicit reference to students developing conceptual understanding or making connections within biology or to other science disciplines and subjects. That said, the cross-cutting concepts are designed to help students understand core ideas, new phenomena, and science and engineering practices. Therefore, conceptual understanding and making connections are implicitly present in the design of the standards and likely to be needed to achieve the performance expectations

The science and engineering practices evidence numerous other DP themes. For example, 'Planning and carrying out investigation' aligns with the DP's themes of investigation skills, collaboration, and awareness of scientific implications – as it states that students should 'plan and conduct and investigations independently and collaboratively' and that this should be done in a 'safe and ethical manner including considerations of environmental, social, and personal impacts'. Furthermore, as well as providing detail on the design and implementation skills, the science and engineering practices also provide detail on the sub-skills involved in undertaking investigations. For instance, 'Obtaining, Evaluating and Communicating Information' details how students should be able to communicate scientific information and ideas in multiple formats. Additionally, the DP's theme of creative and critical thinking skills is strongly present in the science and engineering practices, which include these skills both in reference to investigations, and generally. Indeed, the science and engineering practices explain that students should be able to analyse data (using various techniques). 'Analysing and Interpreting Data' explains that students should be able to analyse data, construct evidence-based arguments, justify reasoning, evaluate and critique information, create and revise models, critically read scientific literature, and design solutions to real-world problems.

The DP's theme of developing technological skills is also present in the science and engineering practices, as they detail how students are expected to select and appropriately use technological tools for observing, measuring, recording, and analysing data – including for using models and performing statistical analysis. Furthermore, the ability to understand and consider the influence of science, engineering and technology on society and the environment as a whole is a cross-cutting theme within the NGSS. Therefore, it follows that there is some alignment with the DP's theme of the social and environmental implications of science. However, performance expectations which include this theme are few in the PS and LS standards.

Other Themes in the NGSS

A couple of outcome themes emerge as receiving greater emphasis in the NGSS when compared to the DP. The ability to use computational thinking is one area which appears to be more prominent in the NGSS performance expectations and in particular, the science and engineering practices. The performance expectations refer to using mathematical representations of physical models to solve problems, whilst the science and engineering practices make explicit reference to using computational simulations. Moreover, the science and engineering practices place more emphasis than is perhaps evident in the DP themes on understanding and applying scientific models. Indeed, in one such practice area students are expected to 'develop and use a model based on evidence to illustrate the relationships between systems or between components of a system'.

Summary

In summary, the performance expectations for the NGSS compare well overall to the DP themes, with similarities in the coverage of acquiring and applying knowledge, creative and critical thinking skills, investigation skills, use of technology, and effective communication and collaboration. However, it can be noted that, at times, themes are more present in the science and engineering practices and cross-cutting concept descriptions than the performance expectations themselves. A couple of themes, including computational thinking and the emphasis on scientific models, emerge as somewhat stronger in focus within the NGSS when compared to DP outcome themes, whilst developing conceptual understanding and considering ethical, social, environmental, and cultural implications of science are not covered in comparable depth in the NGSS.

4.7.2 Content

This section compares and contrasts the content of the DP and NGSS curricula falling within the category of biology. In order to support visual comparison at-a-glance, the biology content in the NGSS is presented below in a diagram that shows the key topics and sub-topics included.

Figure 15: NGSS LS (biology) content visualiser[95]

Core	**LS1: From Molecules to Organisms: Structures and Processes**	LS1.A: Structure and Function	LS1.B: Growth and Development of Organisms	LS1.C: Organization for Matter and Energy Flow in Organisms	LS1.D: Information Processing
	LS2: Ecosystems: Interactions, Energy, and Dynamics	LS2.A: Interdependent Relationships in Ecosystems	LS2.B: Cycles of Matter and Energy Transfer in Ecosystems	LS2.C: Ecosystem Dynamics, Functioning, and Resilience	LS2.D: Social Interactions and Group Behavior
	LS3: Heredity: Inheritance and Variation of Traits	LS3.A: Inheritance of Traits	LS3.B: Variation of Traits		
	LS4: Biological Evolution: Unity and Diversity	LS4.A: Evidence of Common Ancestry and Diversity	LS4.B: Natural Selection	LS4.C: Adaptation	LS4.D: Biodiversity and Humans
Crosscutting concepts	**Patterns**				
	Cause and effect: Mechanism and explanation				
	Scale, proportion, and quantity				
	Systems and system models				
	Energy and matter: Flows, cycles, and conservation				
	Structure and function				
	Stability and change				
Scientific and Engineering Practices	**Asking questions (for science) and defining problems (for engineering)**				
	Developing and using models				
	Planning and carrying out investigations				
	Analyzing and interpreting data				
	Using mathematics and computational thinking				
	Constructing explanations (for science) and designing solutions (for engineering)				
	Engaging in argument from evidence				
	Obtaining, evaluating, and communicating information				

[95] NB: only biology-focused units of work from the life sciences standards have been included. Units pertaining to other scientific disciplines are included in the relevant subject's section.

4.7.2.1 Structure

As with the NGSS PS, the NGSS LS are taught in four years (grade 9-12) within five topics. The performance expectations outlined are blended with core ideas, cross cutting concepts and scientific and engineering practices. In comparison, DP biology is taught through four themes that are separated into four levels of organisation and guiding questions accompanied by content, application of skills and nature of science links.

In LS there is one pathway, with students studying all high school science topics outlined. In contrast, the DP provides two routes for learning; SL and HL, with the HL biology content being more conceptually demanding and explored in greater depth.

DP biology splits into four over-arching themes – i.e. A. Unity and diversity; B. Form and function; C. Interaction and interdependence; D. Continuity and change – with each covering four levels, namely 1. Molecules, 2. Cells, 3. Organisms and 4. Ecosystems. The DP biology course also outlines specific tools to be covered in three areas – experimental, technology and mathematics. Whilst the NGSS do cover elements of each tool, it does not cover them to the same depth and detail; for example, the NGSS biology makes reference to applying general mathematics by using units, symbols and numerical values, and graphing, but does not include processing uncertainties, which is required in DP biology Tool 3: Mathematics. The DP stipulates that students should show awareness of the purpose and practice of 10 biology techniques, which are outlined in Tool 1: Experimental techniques. The NGSS standards make reference to only three of the 10 techniques required in the DP – physical and digital modelling; identifying and classifying organisms and using a variety of sampling techniques/using random; and systematic sampling.

Overall, despite some structural similarities, DP biology has a significantly more defined content structure than the NGSS, with student experiences of those studying the latter likely varying significantly.

4.7.2.2 Content Alignment

To complement the analysis on content alignment, the table below represents a simplified summary of the NGSS's content alignment with the themes and levels in DP biology (SL and HL).

Table 28: Summary of the alignment between DP biology and the NGSS LS standards

DP biology themes and levels	Presence of SL content in the NGSS LS	Presence of AHL content in the NGSS LS
A Unity and diversity		
A1 Molecules		
A2 Cells		
A3 Organisms		
A4 Ecosystems		
B Form and function		
B1 Molecules		
B2 Cells		
B3 Organisms		
B4 Ecosystems		N/A
C Interaction and interdependence		
C1 Molecules		
C2 Cells		
C3 Organisms		
C4 Ecosystems		N/A
D Continuity and change		
D1 Molecules		
D2 Cells		
D3 Organisms		
D4 Ecosystems		
Experimental programme		

Key:

	There is strong presence of this level in the NGSS		*There is partial presence of this level in the NGSS*		*There is little or no presence of this level in the NGSS*

Across all NGSS, five of the sixteen units studied are focused on biology topics, which is likely to result in considerable amount of time being dedicated to the teaching of the subject across the four years of high school.

The NGSS partially cover approximately 80% of the DP biology SL topics, including natural selection, transfers of energy and matter, populations and communities, water, and nucleic acids. However, although many of the topics from DP biology SL are covered, they lack sufficient depth and detail to be comparable. For example, neural signalling is referenced in Structure and Function LS1-2, but the NGSS assessment boundary limits the depth to which it can be studied as it stipulates learning 'does not include interactions and functions at the molecular or chemical reaction level'. Moreover, various DP biology SL topics are altogether absent from the NGSS, including: membranes and membrane transport, organelles and compartmentalisation, transport, enzymes and metabolism, defence against disease, water potential and reproduction.

Although there is considerable alignment of topics between the DP biology SL and NGSS, despite the latter covering content in considerably lower detail and depth, most of the DP biology AHL content is not covered. The few DP biology AHL topics that are covered include nucleic acids, the origin of cells, natural selection, DNA replication, protein synthesis, sustainability and change, and climate change. However, these topics are covered in less depth and detail than would be expected in the DP biology HL course.

Table 29: NGSS content that is not covered by DP biology

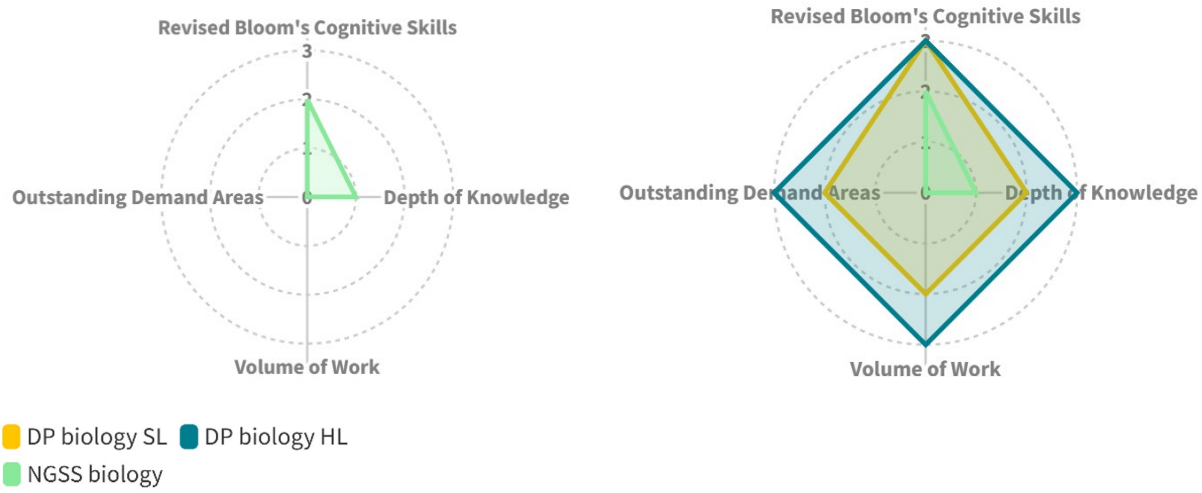
Significant NGSS content which is not included in DP biology*
○ There is no specific content within NGSS LS that is not covered by the DP biology course.

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

4.7.3 Demand

The DP and the NGSS curricula were analysed using the same demand tool in order to create a demand profile for DP biology SL, DP biology HL, and the NGSS Life Sciences standards. These demand profiles are presented below in the form of radar diagrams, with the last diagram showing all profiles superimposed in one place, enabling immediate visual comparison.

Figure 16: Visual representations of subject demand



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:**
  - Both DP biology SL and HL received a score of 3.
  - For the NGSS, a Bloom's score of 2 was deemed appropriate given a predominant focus of the K-12 Framework on knowledge acquisition and application, with some presence (though limited) of higher-order thinking skills, such as evaluation, and emphasis on cross-curricular links. It was noted by the panel that there are good examples of individual states providing more detail on how to apply the standards effectively, though this detail is absent from the NGSS themselves.

- Regarding the scores for **Depth of Knowledge:**
  - DP biology SL received a score of 2 and HL received a score of 3.
  - For the NGSS, the depth of knowledge was seen to meet a score of 1 due to the key pre-requisite requirements and some reference to application of knowledge to real-world context, though the lack of guidance on how knowledge and skills should

be built throughout the years of study made it difficult to ascertain the depth of this knowledge application.

- Regarding the scores for **Volume of Work:**
  - DP biology SL received a score of 2 and HL received a score of 3.
  - In contrast, the NGSS received a score of 0 for volume of work due to the apparently light depth and detail of knowledge and skills evidenced in the documentation. However, it was noted that the real breadth and depth of content, as well as time allocation per theme, may vary significantly from state to state or even school to school, depending on how the standards are applied.

- Regarding the scores for **Outstanding Areas of Subject Demand:**
  - DP biology SL received a score of 2 and HL received a score of 3.
  - As to the NGSS, a score of 0 was awarded as no clear areas of outstanding demand were identified – it was noted that the emphasis on cross-curricular linkages could provide opportunities for potential stretch, but that it was not possible to clearly infer this from the NGSS documentation.

4.8 France

The school system in France is overseen and regulated by the Ministry for National Education and Youth.[96] Secondary education in France is divided into two cycles – lower and upper secondary education. Upper secondary education lasts three years and is provided to students between the ages of 15 and 18 years old. It is the last three years of upper secondary education that constitutes the *Baccalauréat* (FB).[97]

The general pathway (resulting in the *baccalauréat général*) is the main focus of this study; however, students can also choose:

- the technological pathway, resulting in the *baccalauréat technologique* and;
- the professional pathway, resulting in the *baccalauréat professionnel.*

Study in upper secondary is organised into three years and two pedagogical cycles, namely:

- 1st year: *Seconde* (Grade 10: students aged 15 to 16 years old)
- 2nd year: *Première* (Grade 11: students aged 16 to 17 years old)
- 3rd *year: Terminale* (Grade 12: students aged 17 to 18 years old).

Students begin the general pathway in the *Première* year, after completion of the *Seconde* year. The *Seconde* provides an opportunity for students to consolidate and develop their foundational knowledge and skills in order to facilitate a successful transfer from lower to upper secondary education. In the general pathway, students study:

- six common subjects
- three specialty subjects in *Première* and;
- two of these speciality subjects in the *Terminale* year.

Alongside their common and speciality subjects, students can choose one optional subject in the *Première* year and an additional optional subject in the *Terminale* year.

FB life and earth sciences is offered as a speciality subject in the general pathway and this was the focus of the biology subject analysis.

FB life and earth sciences

Life and earth sciences is a specialty subject on the FB *général*. It is a combined subject, bringing together biology, geology and environmental sciences content, and is designed as a two-year subject – studied at *Première* and *Terminale* years – though students in the FB may choose to drop it in their second year. The subject aims to provide students with the appropriate knowledge and skills to prepare them for further study in the disciplines of biology, geology and environmental sciences and scientific careers more broadly. The subject promotes the development of scientific approach skills and associated capabilities in both the *Première* and *Terminale* years.

[96] Government of France, Ministry for National Education and Youth. (2023*). Let's build a committed education system together!* Available: https://www.education.gouv.fr/let-s-build-committed-education-system-together-100037

[97] Ibid.

4.8.1 Learning Outcomes

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

The learning outcome themes for biology were extracted from the aims and assessment objectives of the DP sciences subject group, hence the themes are the same for biology chemistry and physics.

The FB life and earth sciences subject outlines specific 'Skills developed as part of scientific research', of which there are five:

- Pratiquer des démarches scientifiques - Practice scientific methods
- Concevoir, créer, réaliser - Design, create, realise
- Utiliser des outils et mobiliser des méthodes pour apprendre - Use tools and mobilise methods to learn
- Pratiquer des langages - Practice languages
- Adopter un comportement éthique et responsable - Adopt an ethical and responsible behaviour.

These skills characterise the FB's scientific approach, being a key focus throughout students' studies. Alongside these, the FB also provides some examples of associated capabilities. Finally, some additional skills are also discussed in the 'Preamble' section of the FB's documentation. As such, the FB's 'skills developed as part of scientific research', the associated capabilities, and the skills extracted from the Preamble have all been considered when mapping against the DP's learning outcome themes.

Once commencing the general pathway, all students will follow a common curriculum, as well as choose three speciality subjects. FB life and earth sciences is one of the speciality subjects that students may choose to pursue; however, after completing the first year (*Première*) of the subject, they have the option of ceasing their studies by dropping one speciality subject. Therefore, it may be the case that not all students will complete the full two-years of study in FB life and earth sciences. However, the skills outlined in the curricula for both *Première* and *Terminale* years of the FB life and earth sciences are the same, therefore these skills will be developed in all students, regardless of whether they choose to continue to study the subject in the *Terminale* year.

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 FB life and earth sciences curriculum.

Table 30: Presence of the DP sciences subject group learning outcome themes in the FB life and earth sciences curricula

Themes extracted from the learning outcomes of the DP sciences subject group	Presence in FB life and earth sciences	
1. Conceptual understanding and making connections		Present in the 'Practice scientific methods' skill.
2. Use and application of knowledge, methods, tools, and techniques that characterise science		Present in the 'Practice scientific methods' and 'Design, create, realise' skill.
3. Creativity and critical thinking (problem-solving, analysis, evaluation, synthesis)		Somewhat present in the 'Practice scientific methods' skill. Reference to problem-solving, but not analysis or evaluation.
4. Apply skills necessary to carry out insightful and ethical investigations (planning, collecting data, organising, following ethical guidelines)		Present in the 'Practice scientific methods' and 'Design, create, realise' skill.
5. Development of technological skills		Present in the 'practice languages' skill
6. Effective collaboration and communication		Present in the 'practice languages' skill
7. Awareness of global and local problems and the environmental, ethical, cultural, and social impact of science		Somewhat present. The environmental aspect found in the 'Adopt an ethical and responsible behaviour' skill. Ethical, cultural and social impact not evident.

Key:

	This theme is well-evidenced in the skills of the FB.		*This theme is partially evidenced in the skills of FB.*		*This theme is not evident in the skills of the FB.*

Presence of the DP's Learning Outcome Themes

As can be seen in the table above, all learning outcome themes extracted from the DP are at least partially evidenced in the FB life and earth sciences curriculum. Some themes are present across more than one skill, others are reflected in only one. However, overall, the FB life and earth sciences subject focuses on similar skills to those covered in DP biology.

1. Conceptual understanding and making connections

The associated capacities described next to each skill in the FB curriculum show the presence of this theme within the 'practice scientific methods' skill. Here, it is stated that students will "understand that an effect can have several causes" and be able to "distinguish between what is a belief or an opinion and what constitutes scientific knowledge".[98] Whilst there is no specific reference to 'concepts' or 'connections', in order for students to appreciate that one thing can be caused by multiple others, students will have to connect ideas together – possibly from different areas of the curriculum. For example, cancer may be caused by genetic mutations, inherited factors, or environmental factors, and in order to describe and explain this clearly, students would have to link many different ideas to cancer as a singular effect.

[98] Ministry of Education and Youth, France. (2019). *Programme de sciences de la vie et de la Terre de première générale*. Available from: https://eduscol.education.fr/1664/programmes-et-ressources-en-sciences-de-la-vie-et-de-la-terre-voie-gt

To successfully "distinguish between what is a belief or an opinion and what constitutes scientific knowledge", students must have strong conceptual understanding and be confident in their ability to determine whether something is an opinion or a fact. For example, scientific facts are, by definition, verifiable through experimentation and research. To be able to apply this logic, it would be essential that students have thorough understanding of the concepts involved, how to ascertain their validity, and therefore identify them as opinion/belief or scientific fact.

This theme is further highlighted in the 'Preamble' section of the FB life and earth science *Première* curriculum. A paragraph details that students will "integrate into their practices the achievements of other scientific disciplines, in particular physics-chemistry and computer science, and use the concepts of mathematical tools".[99] This is then expanded on to outline the importance of using scientific language consistently across disciplines to support students' understanding.

2. Use and application of knowledge, methods, tools, and techniques that characterise science

Two of the skills in the FB life and earth sciences curriculum show aspects of the use of techniques that characterise science. Within the 'practise scientific methods' skill, there is description of students needing to "Observe, question, formulate a hypothesis [and] experiment", all of which are fundamental components of scientific study. This skill then continues by stating the importance of being able to "interpret results and draw conclusions".[100] Within the 'design, create, realise' skill, students are required to "implement a scientific approach",[101] using tools, concepts, techniques and/or models that they identify as being appropriate for the task. To successfully demonstrate this skill, students would have to apply their knowledge in order to select the most suitable approach for the particular task, as well as the correct use of tools and scientific techniques. This demonstrates similarity between this DP learning outcome theme and the skills outlined in the FB.

3. Creativity and critical thinking (problem-solving, analysis, evaluation, synthesis)

This theme is present to some extent in the skills within the FB, specifically the 'practise scientific methods' skill. The statement "Formulate and solve a scientific problem. Design and implement resolution strategies"[102] demonstrates that students will be creatively finding solutions to problems. However, there is no explicit reference to analysis, evaluation and synthesis within any of the 'skills developed'.

Although critical thinking is not specifically mentioned within the FB skills, the 'Preamble' of the FB life and earth sciences' curriculum document does describe how "the exercise of critical thinking is particularly necessary".[103] Therefore, although this theme is somewhat present in the FB curriculum, it is not emphasised to the same extent as in the DP.

4. Apply skills necessary to carry out insightful and ethical investigations

Once again, this theme can be seen within the 'practice scientific methods' skill in the FB. In addition to its connection to the second theme, described above, the requirement of students

[99] Ibid, p. 3.
[100] Ibid, p. 4.
[101] Ibid
[102] Ibid
[103] Ibid. p. 2.

to “observe, question, formulate a hypothesis, deduce its testable consequences, experiment…interpret results and draw conclusions”[104] is the epitome of scientific study.

The inclusion of experiments is also described in the ‘Preamble’ section of the FB curriculum document Here, it is stated that “experimental activities occupy a central place”[105] in the curriculum, implying that there will be a heavy emphasis on scientific investigations within the teaching of this curriculum.

5. Development of technological skills

This theme is present within the ‘practice languages’ skill of the FB: “Use digital tools. Use data acquisition, simulation and processing software”.[106] The reference to ‘digital’ aspects shows that not only will technology be used, but it is possible that a range of software and digital components will be utilised. This skill goes further to mention that students will “use data acquisition, simulation and processing software”[107] which suggests that aspects of technology will be used in gathering results and data from scientific experiments.

Reference to this theme is also found within the ‘Preamble’ of the FB curriculum document. Here, it is stated that the teaching of FB life and earth sciences should be “in touch with the rapid evolution of knowledge and technologies”,[108] demonstrating an awareness that technologies change and students must be taught a curriculum that includes this. There is also a section of the ‘Preamble’ that is devoted to describing the digital tools that will be used within the course, including; the internet, spreadsheets, computer-assisted experimentation, sensors connected to microcontrollers, databases, geoscientific information systems, digital modelling and programming. The extensive list of various technological aspects within the ‘Preamble’ and the ‘skills developed’ themselves shows that this DP theme is thoroughly evidenced in the FB life and earth science subject.

6. Effective collaboration and communication

There are two skills in the FB curriculum that demonstrate the presence of this theme. The first is: ‘use tools and mobilise methods to learn’ states how students will “cooperate and collaborate within the framework of project approaches”.[109] This implies that students will be carrying out group or project work and will need to work together and collaborate effectively to ensure the project’s successful completion.

The second skill, entitled ‘practice languages’, describes how students will “communicate in a scientifically appropriate language”. Although this does not mention the audience or context, the fundamental aspects of communicating, and the focus of this communication including scientifically appropriate language, reflects the DP’s theme of effective communication.

7. Awareness of global and local problems and the environmental, ethical, cultural, and social impact of science

The environmental component of this theme is very clearly outlined in the ‘adopt an ethical and responsible behaviour’ skill. Students will not only “identify the impacts (benefits and harms) of human activities on environment”,[110] but also understand their responsibilities, both “individual and collective”, for preserving the planet’s resources. These resources are further

[104] Ibid, p. 4.
[105] Ibid, p. 3.
[106] Ibid, p. 5.
[107] Ibid
[108] Ibid
[109] Ibid
[110] Ibid

detailed to be referencing biodiversity, energy resources and mineral resources, which therefore shows that the FB life and earth sciences subject recognises the need for students to respect and play an active role in protecting the world around us.

Within the FB curriculum, there is no specific reference to the other areas within this theme, i.e. the ethical, cultural and social impact of science. Therefore, while the environmental aspect is well covered, there is only partial alignment with this DP theme overall.

Other Themes in the FB

All learning outcome themes within the DP are present in the FB life and earth sciences curriculum. Whilst there are no unique learning outcome themes in the FB, there are slightly some skills have a slightly different weighting from the DP. For example, the communication and collaboration DP theme is demonstrated well, however the FB goes further by emphasising the need for students to 'convince' others. There is particular focus on the ability of students to change someone else's thinking through good oral presentation and argumentation. It is understandable that these aspects are focused on in the FB as students must undertake an oral test as part of the FB, therefore oral presentation skills are essential.

Summary

The DP learning outcome themes are all present in the FB life and earth sciences curriculum within the 'skills developed as part of scientific research' or described in the 'Preamble' sections of the documentation. Some themes are not as emphasised as others; for instance, creativity and critical thinking is less apparent in the FB than in the DP. Moreover, whilst the environmental aspect of theme seven (awareness of the impact of science) is strongly present in the FB, other areas of this theme (ethical, cultural and social) are less evidenced. It may be that these aspects are covered through delivery of the FB subject, however, there is no specific reference to them within the curriculum documentation.

4.8.2 Content

This section compares and contrasts the content of the DP and FB curricula falling within the category of biology. The FB life and earth sciences content is presented in a diagram below, which shows the key topics and subtopics included.

Figure 17: FB life and earth sciences content visualiser

Life and earth sciences ***Première***	**Life and the organisation of living things**	Eukaryotic cells, cell division, DNA replication	DNA mutations and the genome	Inheritance	Enzymes and catalysts
	The Internal Dynamics of the Earth	The structure of the Earth	Seismological and thermal studies	The lithosphere	The dynamics of convergence and divergence zones
	Contemporary Issues of the Planet	Ecosystems and environments	The management of ecosystems		
	Human Body and Health	Mutations and inherited diseases	Mutations and cancer	Bacterial genetics and antibiotic resistance	The Immune System
Life and earth sciences ***Terminale***	**Life and the organization of living things**	Genetics and evolution, the origin of genotypes	Horizontal gene transfers and endosymbioses	Population genetics	The diversity of living organisms
	The geological past of our planet	Time and rocks	Traces of Earth's turbulent past		
	Contemporary planet issues	From the wild to the domesticated plant	The organization of flowering plants	The plant, producer of organic matter	Reproduction and domestication of plants
	The Earth's climate	Understanding the past	The consequences of global warming		
	Human Body and Health	Behaviour, movement and the nervous system	Muscle contraction	The organism and responses to stress	

4.8.2.1 Structure

Both DP biology and FB life and earth sciences are designed as two-year subjects, with both offering the opportunity for students to study biology at different levels – i.e. the FB by allowing students to choose whether to continue to study the FB life and earth sciences subject in the *Terminale* year; the DP by offering students the opportunity to study DP biology at either SL or HL.

One notable difference between the structure of the study of biology in the DP and FB is that in the latter biology is taught as part of the FB life and earth sciences subject. Although DP biology covers some environmental sciences content, such as D4.3 Climate, biology is studied primarily as a single-subject course in the DP.

The DP biology subject is designed through a concept-based approach and organised into four over-arching, discipline-specific themes – A. Unity and diversity, B. Form and function, C. Interaction and interdependence and D. Continuity and change. Each of these themes is divided into four levels of organisation; Molecules, Cells, Organisms and Ecosystems, which provides 16 levels, further divided into topics. The DP biology HL extends learning in 14 of the 16 levels, and more specifically in 27 of the 34 topics and it also contains six additional HL-only topics.

In turn, the FB life and earth sciences content is organised into three main themes: 'Earth, life and evolution', 'contemporary issues of the planet' and 'the human body and health'. All themes draw on daily-life situations and require the use of critical thinking to explore potential solutions to large-scale, real-world problems.

4.8.2.2 Content Alignment

The table below represents a simplified summary of the FB's content alignment with the themes and levels in DP biology (SL and HL).

Table 31: Summary of content alignment between DP biology and the FB

DP biology themes and levels	Presence of SL content in FB life and earth sciences	Presence of AHL content in FB life and earth sciences
A Unity and diversity		
A1 Molecules		
A2 Cells		
A3 Organisms		
A4 Ecosystems		
B Form and function		
B1 Molecules		
B2 Cells		
B3 Organisms		
B4 Ecosystems		N/A
C Interaction and interdependence		
C1 Molecules		
C2 Cells		
C3 Organisms		
C4 Ecosystems		N/A
D Continuity and change		
D1 Molecules		
D2 Cells		

DP biology themes and levels	Presence of SL content in FB life and earth sciences	Presence of AHL content in FB life and earth sciences
D3 Organisms		
D4 Ecosystems		
Experimental programme		

Key:

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

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

FB life and earth sciences covers the vast majority of DP biology SL content to a similar depth, with exception of three levels: B3. Organisms, B4. Ecosystems and D2. Cells. Within B3. Organisms, the FB earth and life sciences covers the structure of arteries and veins but does not include the adaptations of xylem vessels, which is present in the DP. Of the D2. Cells topics, the FB earth and life sciences does not cover medical applications of isotonic solutions.

As to comparison with DP biology HL, the FB earth and life sciences covers only the AHL content in D4. Ecosystems to a similar depth and level of detail. The FB earth and life sciences also partially covers the AHL content in ten levels: A1 and A2 from Unity and diversity; B1 and B3 from Form and function; all levels in C. Interaction and interdependence; and D1, D3 and D4 from Continuity and change. However, the FB's coverage of these DP levels is partial, as the latter includes less depth and level of detail than the DP – for example, DP biology HL covers the molecular mechanisms of photosynthesis, which is not found in the FB curriculum. There are also three DP biology HL levels that are not covered in the FB earth and life science, namely: A3 and A4 from Unity and diversity, and B2 from Form and function. Moreover, the FB earth and life science does not cover any additional biology content that is not included in the DP; nonetheless, as a combined course, it does include additional earth science topics that are not included in DP biology.

The FB life and earth science has similar breadth and depth in the biology levels as the DP biology SL. It has considerably less subject depth that the DP biology HL, with most AHL content having only partial presence in the FB. There is also greater subject breadth in the DP biology HL, as AHL content from three levels is entirely absent from the FB life and earth science subject.

Table 32: FB biology content which is not covered in the DP

Significant FB biology content which is not included in the DP*
○ Earth Science topics only

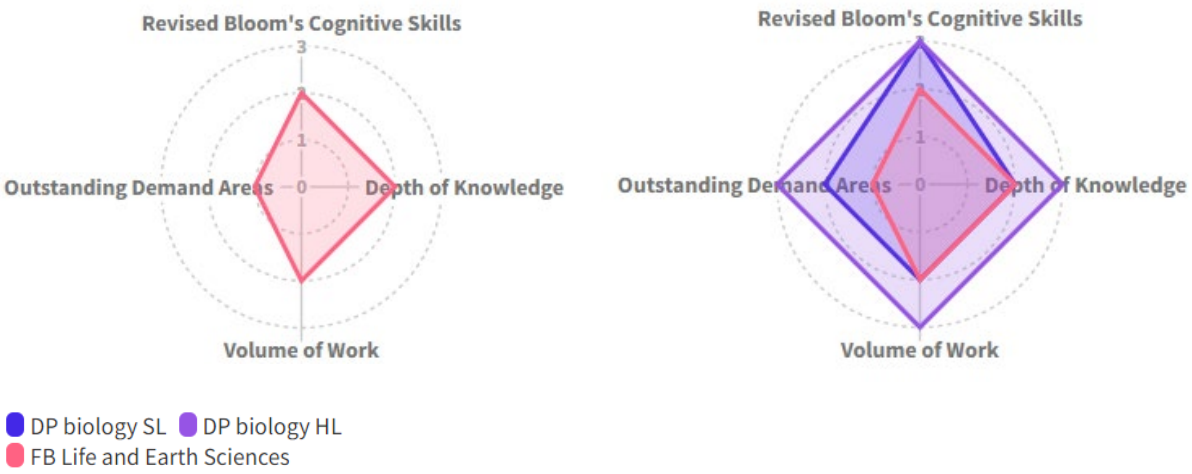
*Significant content mostly does not include topics which are typically studied *prior* to upper secondary.

In summary, the biology content studied in the FB life and earth sciences subject has similar breadth to that of DP biology SL subject, and a similar depth too. In turn, compared to the DP biology HL, the biology content covered in FB earth and life science has somewhat less breadth and significantly less depth.

4.8.3 Demand

The DP and FB curricula were analysed using the same demand tool in order to create a demand profile for DP biology SL, DP biology HL and the FB life and earth sciences. The FB demand profile is presented below in the form of a radar diagram, along with a diagram showing all DP and FB profiles superimposed in one place, enabling immediate visual comparison.

Figure 18: Visual representations of subject demand



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**:
  - Both DP biology SL and HL received a score of 3 for Bloom's cognitive skills.
  - A score of 2 was awarded to FB life and earth sciences. This is due to there being a strong presence of analysis in the 'skills developed', and some reference to synthesis and design. However, creativity and evaluation were not found to be predominant, therefore a score of 3 could not be awarded.

- Regarding the score for **Depth of Knowledge**:
  - DP biology SL was deemed to merit a score of 2 for depth of knowledge and DP biology HL received a score of 3.
  - The FB life and earth sciences was given a score of 2 for depth of knowledge. The presence of analysis within the FB 'skills developed' and some content areas suggest that some time is spent beyond foundational knowledge and understanding. However, the cognitive demands of the FB are often not complex and abstract, preventing 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) and the HL subject was deemed to have a heavy workload and received a score of 3.

  - A score of 2 was given to the FB life and earth sciences for the volume of work category. The relatively high number of themes within the subject, coupled with the teaching of physics and chemistry together, results in a standard to short time allocation per theme. Although some time is spent on issues beyond basic conceptual depth, this is not the majority of the course; therefore, a judgement of 2 was reached.

- Regarding the scores for **Outstanding Areas of Subject Demand**:
  - DP biology SL was awarded a score of 2 and HL received a score of 3.
  - The FB life and earth sciences was awarded a score of 1 for outstanding areas of subject demand. The transdisciplinary approach to teaching the subject allows for potential stretch, as does the 'project-focused' and collaborative approach which is outlined in the FB 'skills developed'. Together, these aspects were deemed to warrant a score of 1 area of subject demand.

4.9 Spain

The school system in Spain is overseen by the Ministry of Education and Vocational Training, but is decentralised into 17 autonomous regions. As such, while the Ministry oversees the core curriculum and assessment, the regions can determine specific procedures and dictate some subjects within the overall selection.

Overall, the Spanish system is divided into primary school, lower secondary education, and upper secondary education. Upper secondary education is non-compulsory and lasts for two years, being attended by students between the ages of 16 and 18 years old.[111] During upper secondary, students can take the Spanish *Bachillerato* (SB).

The SB is offered through four different streams (i.e. modalities), which students can choose from, in line with their specific interests and career plans:

- the Arts modality (includes two pathways);
- the Sciences and Technology modality;
- the Humanities and Social Sciences modality; and
- the General modality.

Students from all modalities study a range of subjects from different categories, including:

- **Common subjects:** these are subjects taken by all students regardless of their modality.
- **Modality subjects:** these are subjects taken by students in the same modality.
- **Elective subjects:** these are optional subjects that students can choose to study.

In addition to the common and modality subjects above, students in the SB also study elective subjects. The specific subjects offered are determined by the Spanish regional educational authorities but should include at least one second foreign language.[112]

The mathematics studied as part of the Science and Technology modality is the main focus of the mathematics comparison analysis. The below table displays the subjects within this modality:

Table 33: Subjects offered in the Science and Technology modality

Modality	Year of study	Subjects
Science and Technology	Year 1	Mandatory subject: Mathematics I
		Two subjects to be chosen from: • Biology, geology and environmental sciences • Technical drawing I • Physics and chemistry Technology and engineering I

[111] Government of Spain, Ministry of Education and Vocational Training (n.d). Compulsory Secondary Education, https://educagob.educacionyfp.gob.es/ensenanzas/secundaria.html ; Government of Spain, Ministry of Education and Vocational Training (n.d). Bachiller Certificate, https://educagob.educacionyfp.gob.es/ensenanzas/bachillerato.html

[112] Government of Spain, Ministry of Education and Vocational Training (n.d). General information of the Bachillerato. Elective subjects. https://educagob.educacionyfp.gob.es/ensenanzas/bachillerato/informacion-general/organizacion.html

Modality	Year of study	Subjects
	Year 2	Mandatory subject: Mathematics II or Mathematics Applied to Social Sciences II
		Two subjects to be chosen from: • Biology • Technical drawing II • Physics • Geology and environmental sciences • Chemistry Technology and engineering II

The following subjects from the Science and Technology Modality were used in the biology subject comparisons.

SB biology, geology and environmental sciences (BGE)[113]
Biology, geology and environmental sciences is a one-year modality subject that students may opt to study on the first year of the Science and Technology modality of the SB. The subject combines biology, geology and environmental sciences content, building on prior scientific knowledge and skills acquired during lower secondary education. It intends to provide a strong foundation for further physics, biology and/or geology study in the following year.

SB biology[114]
Biology is a one-year modality subject that students may opt to study on the second year of the Science and Technology modality of the SB. It builds on the SB biology, geology and environmental sciences subject offered in the SB's first year, aiming to provide the appropriate foundation of knowledge and skills required for further scientific study at higher education level. Students must have completed the first-year SB biology, geology and environmental sciences subject in order to take SB biology in their second year.

The second year of the SB allows students to choose what subject to specialise in. If they continue their studies in biology, this year provides a more complete biology syllabus which includes various challenging topics and practical experiments that are more specific to the subject area of biology.

4.9.1 Learning Outcomes

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

The learning outcome themes for biology were extracted from the aims and assessment objectives of the DP Sciences subject group, hence the themes are the same for biology chemistry and physics.

[113] Ministry of Education and Vocational Training, Spain. (n.d.). *Biología, Geología y Ciencias Ambientales*. Available from: https://educagob.educacionyfp.gob.es/curriculo/curriculo-lomloe/menu-curriculos-basicos/bachillerato/materias/biologia-geologia-cienciasamb/desarrollo.html
[114] Ministry of Education and Vocational Training (n.d.), Biología. Available from: https://educagob.educacionyfp.gob.es/curriculo/curriculo-lomloe/menu-curriculos-basicos/bachillerato/materias/biologia/desarrollo.html

The learning outcomes for the SB were drawn from the 'Specific Competences' (SCs) of both the SB biology, geology and environmental sciences and the SB biology subjects. While there are some minor differences between the SCs of both SB subjects, these did not affect the level of alignment with the DP learning outcome themes; as such, most of the analysis applies to both subjects, flagging the slight differences observed when appropriate.

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 SB biology curricula.

Themes extracted from the learning outcomes of the DP sciences subject group	Presence in the SB	
1. Conceptual understanding and making connections		Present in both Biology and Biology, Geology and Environmental Sciences.
2. Use and application of knowledge, methods, tools, and techniques that characterise science		Present in both Biology and Biology, Geology and Environmental Sciences.
3. Creativity and critical thinking (problem-solving, analysis, evaluation, synthesis)		Present in both Biology and Biology, Geology and Environmental Sciences, but more apparent in the SCs of Biology.
4. Skills for scientific inquiry		Present in both Biology and Biology, Geology and Environmental Sciences, but more apparent in the SCs of Biology.
5. Development of technological skills		Not explicitly present but may perhaps be inferred from some of the skills – see full analysis below.
6. Effective collaboration and communication		Somewhat present, slightly more apparent in the SCs for Biology, Geology and Environmental Sciences.
7. Awareness of global and local problems and the environmental, ethical, cultural, and social impact of science		Partially present, slightly more apparent in the SCs for Biology, Geology and Environmental Sciences.

Table 34: Presence of the DP sciences subject group learning outcome themes in the SB biology curricula

Key:

	This theme is well-evidenced in the competences of the SB		*This theme is partially evidenced in the competences of the SB*		*This theme is not evident in the competences of the SB.*

Presence of the DP's Learning Outcome Themes

As can be seen in the table above, almost all learning outcome themes extracted from the DP are present to some extent in the SB biology curricula, with the exception of the development of technology skills. The below write-ups provide a summary of the extent to which each DP theme is present in the SB.

1. Conceptual understanding and making connections

Many of the SB biology SCs demonstrate the importance of conceptual understanding and making connections (within the subject, and with other science subjects). For example, specific competence 1 states that students will interpret "information and data from scientific

works".[115] These "scientific works" are not necessarily specific to biology, so it can be inferred that these may incorporate aspects of physics, chemistry, general science, or other subjects such as geology. SC 3 describes how students will "analyse research, or dissemination works related to the biological sciences";[116] in order to be capable of this, students will have to make connections within, and across, science subjects. SC 4 includes the description of how students will "explain phenomena related to biological sciences";[117] to succeed in this competence, it is essential that students make connections and have strong conceptual understanding. The similarity between the DP and SB regarding this theme is further enhanced by specific competence 6, where students will "analyse the function of the main biomolecules, bioelements and their biochemical structures and interactions".[118]

2. Use and application of knowledge, methods, tools, and techniques that characterise science

The SB biology specific competence 3 states that students will check that "they have followed the steps of scientific methods",[119] while SC 4 also reinforces this theme by describing how students would "reformulate the procedure if necessary".[120] SC 4 summarises techniques that characterise science when it states "pose and solve problems…critically analysing solutions…reformulating the procedure…to explain phenomena".[121] The SCs of the SB biology, geology and environmental sciences curriculum also reflect this theme, with specific competence 3 including "following the steps of scientific methodologies",[122] therefore showing strong coverage of the importance of techniques that characterise science.

3. Creativity and critical thinking (problem-solving, analysis, evaluation, synthesis)

Some of the SCs within the SB also show the importance of critical thinking and the focus on skills such as problem-solving, analysis, evaluation and synthesis. Throughout nearly all the SCs, students are required to "analyse concepts, processes…critically evaluate…critically analyse" various components.[123] There are also references to students having to compare and contrast sources of information in order to evaluate it, and specific competence 4 describes students being able to "pose and solve problems".[124] In addition to this, specific competence 3 requires students to "analyse research, critically checking their veracity"[125], which further highlights the presence of this theme in the SB biology curriculum.

4. Skills necessary for insightful and ethical investigations

Within the SCs for SB biology, only specific competence 4 relates to this DP theme: "…using appropriate strategies…and reformulating the procedure if necessary".[126] This is referring to students' investigation skills as it is written in the context of explaining scientific phenomena; however, this theme is not as prevalent in the SB as it is in the DP. Throughout the SB biology SCs, there are references to scientific procedures and scientific investigations, but these are made within the context of students' analysis and evaluative skills, rather than planning and

[115] Ministry of Education and Vocational Training, Spain. (n.d.). *Biología.* Available from: https://educagob.educacionyfp.gob.es/curriculo/curriculo-lomloe/menu-curriculos-basicos/bachillerato/materias/biologia/desarrollo.html
[116] ibid
[117] ibid
[118] ibid
[119] ibid
[120] ibid
[121] ibid
[122] Ministry of Education and Vocational Training, Spain. (n.d.). *Biología, Geología y Ciencias Ambientales*. Available from: https://educagob.educacionyfp.gob.es/curriculo/curriculo-lomloe/menu-curriculos-basicos/bachillerato/materias/biologia-geologia-cienciasamb/desarrollo.html
[123] Ministry of Education and Vocational Training, Spain. (n.d.). Biología.
[124] ibid
[125] ibid
[126] ibid

carrying out the investigations themselves. This theme has slightly more presence within the SCs of the SB biology, geology and environmental sciences curriculum. Specific competence 3 discusses this theme when describing how students "design, plan and develop research projects following the steps of scientific methodologies".[127] Due to only two clear references being made to this theme in the SB, it can be ascertained that the DP places more emphasis on this theme than the SB.

5. Development of technological skills

The development of technology skills is not as explicitly referenced in the SB as it is in the DP. Some aspects of technology could be inferred from the wording of the SB's SCs, but this is open to interpretation; as such, it cannot be stated with confidence that the SB contains this theme. There are some statements from the SB biology SCs that have the potential to require technology; for example, specific competence 1 states that students will be interpreting and transmitting information and data from scientific works "using different formats",[128] and specific competence 2 describes how students will "locate and use reliable sources".[129] Technology may be used for each of these processes, but as none of the SC statements references technology specifically, there is no clear evidence that this DP theme is present in the SB.

The evaluation criteria for specific competence 1 do have some reference to technology skills when it is discussing transmission of information or opinions: "using the appropriate format (models, graphs, tables, videos, reports, diagrams…or digital content, among others)".[130] Although this is not stated as part of the competence itself, it is described as what students would need to do in order to demonstrate their successful grasp of that competence.

6. Effective collaboration and communication

Specific competence 1 of SB biology is the only one that references communication skills, and it is not as clearly outlined as it is in the DP – it simply describes how students will interpret information from scientific works "and argue about them".[131] This is not a direct reference to communication skills; however, in order to argue about something, a student's communication skills must be developed to a certain degree. There is no further reference to working collaboratively, presenting an idea or project, or engaging in a debate; therefore communication and collaboration skills are much more prevalent in the DP than they are in the SB.

The SB's 'evaluation criteria' dissect this specific competence further and supports the presence of this DP theme. The evaluation criteria state that successful demonstration of this SC would be that the student would "communicate information or reasoned opinions…transmitting them in a clear manner…and responding in a well-founded and precise manner to the questions that may arise".[132] This demonstrates the presence of the 'communication' aspect of this DP theme, but there is still no particular reference to the 'collaboration' component, and therefore this theme is still only partially present in the SB.

7. Awareness of global and local problems and the environmental, ethical, cultural, and social impact of science

There is only one specific competence that aligns with this DP theme in SB biology – that of specific competence 5. It details how students will "critically analyse certain actions related to

[127] Ministry of Education and Vocational Training, Spain. (n.d.). *Biología, Geología y Ciencias Ambientales*.
[128] ibid
[129] ibid
[130] ibid
[131] ibid
[132] ibid

sustainability and health" and further develops this idea by outlining how they will then "argue about the importance of adopting a sustainable and healthy lifestyle".[133] The same specific competence within the SB biology, geology and environmental sciences curriculum has a slightly different wording but further echoes this sentiment, describing that students will design and execute initiatives "related to environmental conservation, sustainability and health…to promote healthy lifestyles".[134]

Within this DP theme, there is the inclusion of the social, ethical and cultural impact of science, which is only evident in the SB's evaluation criteria for this specific competence. Here, it is stated that to successfully demonstrate this competence, students will understand research as something that is "in constant evolution influenced by the political and social context".[135] Whilst this does not go into further detail, it does show that there is some presence of this part of the DP theme.

Other Themes in the SB

Whilst there are no overall themes in the SB biology curricula that are not present in the DP, there is reference to an aspect not found so specifically within the DP. In the evaluation criteria for specific competence 3, the SB refers to the fact that students should "highlight the role of women"[136] in scientific research. The specific understanding of women's role in research is not necessarily missing from the DP, but it is not as overtly expressed as it is in the SB.

Summary

There are many similarities between the learning outcome themes of the DP and the specific competences covered by the SB. Some themes, such as critical thinking and analysis, are clearly expressed in the specific competences themselves, whereas others, such as collaboration and communication, are described within the evaluation criteria of the specific competences. Overall, all DP learning outcome themes are represented to some extent in the SB biology curriculum.

4.9.2 Content

This section compares and contrasts the content of the DP and SB curricula falling within the category of biology. The SB biology content is presented below in a diagram which shows the key topics and subtopics.

[133] ibid
[134] ibid
[135] Ministry of Education and Vocational Training, Spain. (n.d.). *Biología.*
[136] ibid

Figure 19: SB biology content visualiser

SB biology, geology and environmental sciences	**A. Scientific project**	Formulating hypotheses and researching	Scientific laboratory or field experiments	Analysis and communication of results	Scientific works and people engaged in science	The evolution of scientific knowledge	
	B. Ecology and sustainability	Environmental Impact	The ecological footprint	Local and Global sustainability initiatives	Ecosystems and Biodiversity	Climate change	
	C. History of the Earth and Life	Geological time	The history of the Earth	The Geological record	Life on Earth	Taxonomy and Classification	
	D. Earth's dynamics and composition	Atmosphere, hydrosphere and geosphere	Plate tectonics	Human activities	Classification and Structure of rocks and minerals		
	E. Animal physiology and histology	Nutrition	Physiology and co-ordination	Reproduction			
	F. Plant physiology and histology	Photosynthesis	Transport in plants	Plant responses	Reproduction	Adaptations	
	G. Microorganisms and acellular forms	Classification of bacteria	Bacterial metabolism	Zoonoses and Epidemics	Antibiotic Resistance	Acellular forms (viruses, viroids and prions)	
SB biology	**A. Biomolecules**	Organic and inorganic molecules	Water and mineral salts	Chemical characteristics	Monosaccharides, disaccharides and polysaccharides	Proteins, amino acids and vitamins	Nucleic acids
	B. Molecular Genetics	DNA replication in prokaryotes	Gene expression in prokaryotes	Mutations	Cell differentiation	Prokaryotic and eukaryotic genomes	
	C. Cell Biology	Cell theory and microscopy	Plasma membrane structure and transport	Cellular structures	The cell cycle and cell division	Cancer	
	D. Metabolism	Anabolism and catabolism	Aerobic and anaerobic respiration	Heterotrophic and autotrophic nutrition			
	E. Biotechnology	Genetic engineering techniques	The importance and impact of biotechnology				
	F. Immunology	What is immunity?	Primary defenses	Innate and specific immunity	Humoral and cellular immunity	Phases of infectious diseases	Pathologies of the immune system

4.9.2.1 Structure

The DP and SB programmes are both taught over two years, with both offering the opportunity for students to study biology at different levels – i.e. the SB offers a combined SB biology, geology and environmental sciences subject in the first year, with the option to take the specialist SB biology subject in the second year; the DP offers students the opportunity to study DP biology at either SL or HL.

One notable difference between the structure of the biology subject area in the two programmes is the combined nature of the SB's first-year biology, geology and environmental sciences subject. Although DP biology covers some environmental sciences content, such as D4.3 Climate change, biology is studied primarily as a single-subject course in the DP.

The DP biology subject is designed through a concept-based approach and organised into four over-arching, discipline-specific themes – A. Unity and diversity, B. Form and function, C. Interaction and interdependence and D. Continuity and change. Each of these themes is divided into four levels of organisation; Molecules, Cells, Organisms and Ecosystems. These levels of organisation are then organised into topics. Overall, DP biology SL consists of 16 levels which are divided into 34 topics, while the DP biology HL extends learning in 14 of the 16 levels, and more specifically in 27 of the 34 topics and it also contains 6 additional HL-only topics.

SB biology, geology and environmental sciences is structured into seven blocks, with the first block, Science project, focusing on the development of practical, investigative and analytical skills. The other six blocks of content are: Ecology and sustainability, History of Earth and Life, Earth's dynamics and composition, Animal physiology and histology, Plant physiology and histology and Microorganisms and acellular forms. SB biology, which is the optional second year modality subject, consists of six blocks of learning which are: Biomolecules, Molecular genetics, Cell biology, Metabolism, Biotechnology and Immunology. In this sense, both SB biology, geology and environmental sciences and SB biology organise their content around a higher number of overarching themes than DP biology.

4.9.2.2 Content Alignment

The table below represents a simplified summary of the SB's content alignment with the themes and levels in DP biology (SL and HL).

Table 35: Summary of content alignment between DP and SB biology

DP biology themes and levels	Presence of SL content in SB biology, geology and environmental sciences	Presence of AHL content in SB biology, geology and environmental sciences	Presence of SL content in SB biology	Presence of AHL content in SB biology
A Unity and diversity				
A1 Molecules				
A2 Cells				
A3 Organisms				
A4 Ecosystems				
B Form and function				
B1 Molecules				
B2 Cells				
B3 Organisms				
B4 Ecosystems		N/A		N/A
C Interaction and interdependence				
C1 Molecules				
C2 Cells				
C3 Organisms				
C4 Ecosystems		N/A		N/A
D Continuity and change				
D1 Molecules				
D2 Cells				
D3 Organisms				
D4 Ecosystems				
Experimental programme				

Key:

	Strong presence of this level in the SB		*Partial presence of this level in the SB*		*Little or no presence of this level in the SB*

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

Of the 16 DP biology levels, SB biology, geology and environmental sciences covers four of these to a similar depth and level of detail as DP SL. These levels are: A4. Ecosystems, C2. Cells, C4. Ecosystems, and D4. Ecosystems. Additionally, there are eight DP biology levels that are not covered to the same level of detail as SL, namely: A2. Cells, A3. Organisms, B3. Organisms, B4. Ecosystems, C1. Molecules, C3. Organisms, D2. Cells, and D3. Organisms. For example, in B3. Organisms, the SB covers the transport of water in plants, but the adaptations of the veins and arteries to transport blood are not covered. Moreover, SL content from four of the levels in DP biology is entirely absent from the SB biology, geology and environmental sciences, namely A1. Molecules, B1. Molecules, B2. Cells, and D1. Molecules.

In comparison to DP biology HL, the SB biology, geology and environmental sciences fully cover one (C3. Organisms) of the 14 levels to a similar depth and level of detail HL. It also contains partial presence of AHL content in seven of the levels, which are A2, A3 and A4 from Unity and diversity, B3. Organisms, C2. Cells, D3. Organisms, and D4. Ecosystems. Moreover, SB biology, geology and environmental sciences does not cover AHL content from the following six DP biology levels: A1. Molecules, B1. Molecules, B2. Cells, C1. Molecules, D1. Molecules and D2. Cells.

In turn, SB biology covers four DP biology levels in similar depth and detail to SL, namely: A1. Molecules, A2. Cells, B1. Molecules, and D2. Cells. There is also partial presence of SL content from three other levels, namely: B2. Cells, C3. Organisms, and D2. Cells. For example, for B2. Cells, SB biology covers the structure of a plasma membrane, but does not cover the differences between totipotent, pluripotent and multipotent stem cells, which are covered in DP biology SL.

Compared to DP biology HL, SB biology covers AHL content from two of the 14 levels, which are B1. Molecules and C1. Molecules. Moreover, AHL content from four other levels is partially present in SB biology, namely: A1. Molecules, B2. Cells and D1. Molecules, and D2. Cells. However, SB biology does not cover AHL content from six levels, including the climate change content in the D4. Ecosystems. Nonetheless, SB biology does cover additional content on the importance and impact of biotechnology: applications in health, agriculture, environment, new materials, food industry, and prominent role of microorganisms, which is not covered in DP biology.

In summary, SB biology, geology and environmental sciences has less subject depth and breadth than DP biology SL, with four levels not being covered and a further eight levels being only partially present. SB biology, geology and environmental sciences does cover some DP biology HL-only content – with AHL content from 14 levels being at least partially present – but overall HL has significantly more depth and breadth.

When judging the alignment between SB biology, geology and environmental and SB biology combined, SL and AHL content in all DP levels is at least partially covered by the SB, with a particularly aligned overall coverage of C1. Molecules and A1. Molecules.

The experimental programme of the DP is also partially covered in the SB through multiple references to students formulating and designing their own experiments. Investigative techniques are mentioned throughout the SB; however, they are interwoven amongst content, rather than being specifically focused on in their own right through a project-based approach. Therefore, due to the difference in delivery and emphasis on practical skills, the SB does not fully align with the DP's experimental programme.

Within the SB there are some areas of content that are not covered by the DP. The SB puts particular focus on the importance of biotechnology and the impact that this has on individuals, society and the world. The SB also includes the use of biotechnology in various industrial areas such as health, agriculture, the environment, food production and creation of new materials. Although the DP does include micro-organisms in the biology course, there is a heavier emphasis in the SB on these aspects. For example, the differences between eubacteria and archaeobacteria, the mechanisms of bacterial metabolism and characteristics of acellular forms (viruses, viroids and prions). These elements are not as prevalent in the DP.

Table 36: SB biology content which is not covered in DP biology

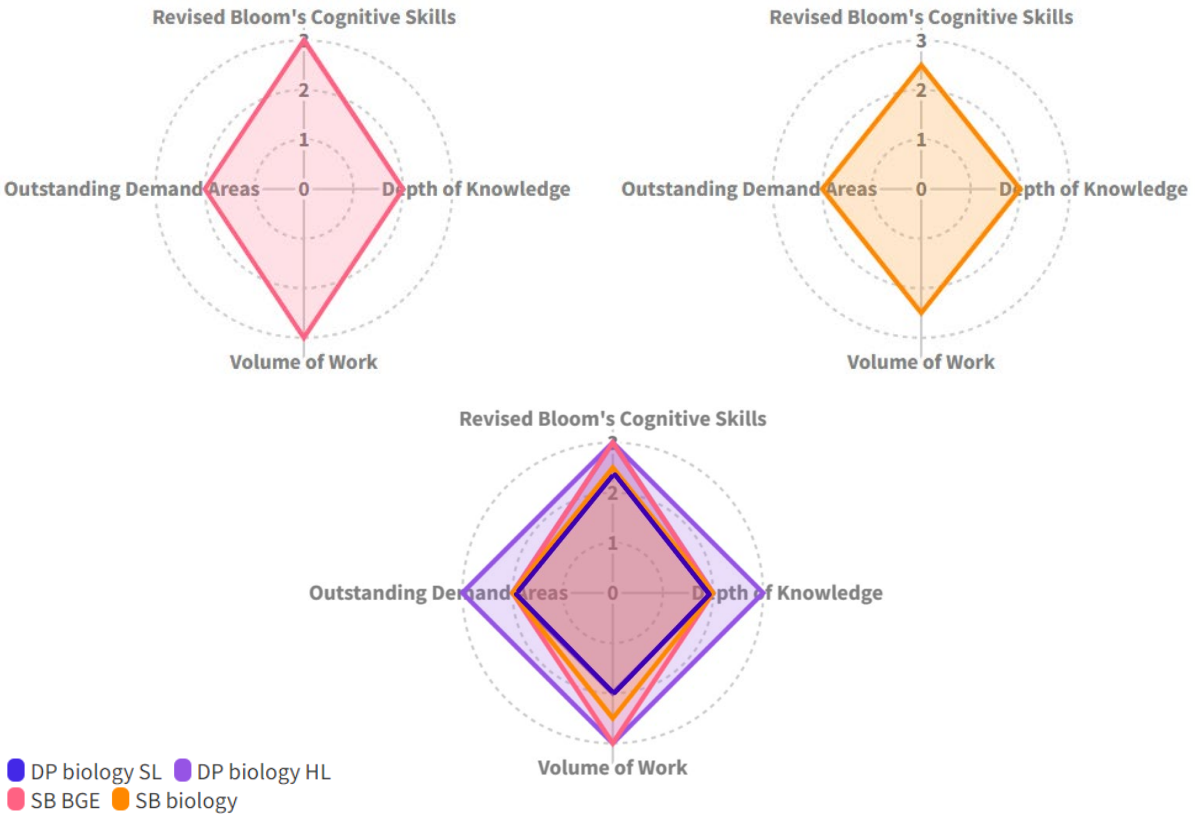
Significant SB biology content which is not included in the DP*
○ The importance and impact of biotechnology ○ applications of biotechnology in health, agriculture, environment, new materials, food industry ○ Detailed aspects of micro-organisms.

In summary, there is a strong alignment between the SB biology subjects and DP biology, with the former covering all DP themes and levels to at least some extent. Overall, SB biology surpasses DP biology SL in breadth and depth, and matches DP biology HL in breadth, though it does not feature the same depth of content as the latter.

4.9.3 Demand

The DP and SB curricula were analysed using the same demand tool in order to create a demand profile for DP biology SL, DP biology HL, SB biology, geology and environmental sciences (BGE) and the SB biology. SB biology represents the overall two-year pathway of studying biology study. These SB profiles are presented below in the form of radar diagrams, with the last diagram showing all DP and SB profiles superimposed in one place, enabling immediate visual comparison.

Figure 20: Visual representations of subject demand



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**:
  - Both DP biology SL and HL received a score of 3.
  - A score of 3 was awarded to SB biology, geology and environmental sciences course. This was due to the strong presence of evaluation and creation skills in the SCs; there is a predominant focus on analysis and evaluation within the SB, thereby warranting a score of 3.

  - SB biology received a score of 2.5 for Bloom's cognitive skills, as whilst all six SCs of the second year course include analysis, and some describe critical analysis of actions, concepts and processes, they do not feature the same predominant focus on synthesis or creation as the SB BGE. Indeed, by itself, the second-year course warranted a score of 2, thus on overall score of 2.5 was deemed appropriate for the pathway.

- Regarding the score for **Depth of Knowledge**:
  - DP biology SL received a score of 2 and DP biology HL received a score of 3.
  - A score of 2 was given to the SB biology, geology and environmental sciences subject. There is evidence that students will engage in complex reasoning and higher-level thinking, but it is not evident that this takes place over an extended period of time, preventing a score of 3.
  - The SB biology course was judged to merit a score of 2 for depth of knowledge. Whilst there is evidence of complex reasoning, analysis and critical evaluation present throughout the SCs, there is not enough evidence that this is occurring over an extended period of time, preventing a score of 3.

- Regarding the scores for **Volume of Work**:
  - DP biology SL received a score of 2 for a moderate-heavy workload and DP biology HL received a score of 3 for a heavy workload.
  - For SB biology, geology and environmental sciences, a score of 3 was given for volume of work. The main rationale for this was the time constrained-nature of the subject, rather than the complexity of content per se. There is a lot of content that is being delivered in a very restricted time (87.5h), justifying a score of 3.
  - A score of 2.5 was given to the SB biology subject for volume of work. A standard amount of time was deemed to be devoted to content coverage and a significant proportion of that time is spent on issues beyond basic conceptual depth. Thus, combined with the heavy-workload of the first year, a time allocation of 2.5 was deemed appropriate for the SB biology pathway.

- Regarding the scores for **Outstanding Areas of Subject Demand**:
  - DP biology SL received a score of 2 and DP biology HL received a score of 3.
  - The SB biology, geology and environmental sciences subject received a score of 2 for outstanding areas of subject demand. The transdisciplinary approach to the course coupled with the science project students are required to complete and the real-life applications of content promoted throughout the subject result in a significant number of potential stretch areas for students.
  - The SB biology pathway received a score of 2 for outstanding areas of demand, as the second-year course continued the transdisciplinary approach taken in SB BGE, as well as other small areas of potential stretch for students. Cumulatively, this was still a significant, rather than 'high', number of areas, thus remained as a score of 2, rather than increasing to a 3.

4.10 Brazil

The education system in Brazil is overseen by the Ministry of Education (*Ministério da Educação*, MoE). Broadly, the Brazillian education system is divided into basic education (*educação básica*) and higher education (*ensino superior*). Basic education is compulsory and spans three stages: early childhood education (*ensino infantil*); elementary school (*ensino fundamental*) – which encompasses both primary and lower secondary; and high school (*ensino médio)*.

The upper secondary stage of education, the e*nsino médio* (high school) takes place over three years (grades 1-3) and is delivered in general or technical institutions.[137] This stage acts as a continuation from primary education, and as a preparatory stage prior to higher education or vocational training.

The *National Guidelines for High School Education, National Common Curricular Base (BNCC),* and *Curricular References for the Preparation of Formative Itineraries* are key to the organisation and structure of high school education in Brazil and are referred to collectively here as the Brazilian High School Curriculum (BHSC).

As part of the BHSC, the BNCC describes the essential learning and minimum standards to be achieved for all pupils. At school level, the curriculum is set by state education secretariats and municipal education authorities. Providing they meet the standards outlined in the BNCC, educational institutions and networks may construct their curriculum as they feel is pertinent to their context. The BNCC thus underpins all curriculum offerings, but rather than being a curriculum in itself, it provides guidance for content planning, allowing for flexibility at the state and school-level. [138]

Learning in the BHSC is structured into basic general education and formative itineraries. Basic general education is guided by the BNCC, which arranges the essential learning into the four areas of knowledge below:

- Language and Technology (including Portuguese)
- Mathematics and Technology
- Natural Sciences and Technology
- Applied Human and Social Sciences. [139]

The other component of the BHSC is the formative itineraries, which schools may offer based on regional and local needs, interests and resources. Formative itineraries focus on deepening and expanding learning in one of the areas of knowledge, or on technical and professional training.[140] Integrated itineraries may also be offered which combine the study of one area of knowledge with another area, or with technical and professional training.

[137] OECD. (2021). *Education Policy Outlook in Brazil: With a focus on national and subnational policies*. *OECD Education Policy Perspectives, No. 38.* OECD Publishing, Paris. Available from: Education Policy Outlook in Brazil: With a focus on national and subnational policies | OECD

[138] OECD. (2021). *Education in Brazil: An International Perspective*. *The Brazilian education system*. OECD Publishing, Paris.

[139] Ministry of Education. National Education Council. Basic Education Chamber. (2018). *Resolution No.3, of November 21, 2018*. p. 5-6 (art.11).

[140] Ministry of Education. National Education Council. Basic Education Chamber. (2018). *Resolution No.3, of November 21, 2018*. p. 7 (art.12)

As such, the analysis uses the following subjects for comparison to DP biology.

BHSC Natural Sciences and Technology (Basic General Education) – BHSC NST (BGE)
In the BHSC, Natural Sciences and Technology (NST) is a compulsory area of knowledge for the basic general education (BGE) component of high school. NST encompasses multiple science disciplines (physics, chemistry and biology) and aims to build on the learning of elementary school, deepening students' knowledge in the themes of Matter and Energy, Life and Evolution, and Earth and Universe. Students are also expected to become more aware of the social, historical and cultural contextualization of science and technology; and of research process and practices**.** BHSC NST (BGE) is based upon the specific competencies and skills prescribed by the BNCC for NST.[141] To support the content analysis, the Rio de Janeiro Referential Curriculum (RJRC) was consulted to gain further insights into the physics, chemistry, and biology topics covered in BHSC NST (BGE). [142]

BHSC Natural Sciences and Technology (Formative Itinerary) – BHSC NST (FI)
In the BHSC, Natural Sciences and Technology is an area of knowledge that students may choose to specialise in for the formative itinerary (FI) component of high school. Formative itineraries are curricular units which are designed for students to deepen their knowledge and prepare for further studies or careers. BHSC NST (FI) is based upon the 'Curricular References for the Preparation of Formative Itineraries', which guide the development of this subject by each state.[143] Again, the RJRC is consulted to provide further insights into the type of content covered in BHSC NST (FI).[144]

4.10.1 Learning Outcomes

This section compares and contrasts the learning outcomes of curricula falling within the category of science. The learning outcomes articulated by the DP and BHSC are the same for all sciences, therefore these are considered for the science subject area as a whole in this section.

The DP learning outcome themes for science were extracted from the aims and assessment objectives of the DP sciences subject group. BHSC Natural Science and Technology (NST) learning outcomes are presented as specific competencies and specific skills. For formative itineraries specifically, additional skills are given, which are based on the formative itinerary structuring axes. Moreover, the BHSC also articulates general competencies for high school education which have also been considered when relevant here.

The following summary table demonstrates the learning outcome themes that were extracted from DP sciences and indicates if and where they were judged to have presence within the learning outcomes of BHSC Natural Sciences and Technology (NST).

[141] Brazil, Ministry of Education. (2018). *5.3.1. The area of Natural Sciences and their Technologies: Specific competencies and skills*. BNCC. Available from: National Common Curricular Base - Education is the Base (mec.gov.br)
[142] Rio de Janeiro State Government, Department of Education. (2022). *Natural Sciences and Technology*. High School Referential Curriculum for the State of Rio de Janeiro. p. 81-91. Available from:
[143] Brazil, Ministry of Education. (n.d.). *Curricular References for the Preparation of Formative Itineraries*.
[144] Rio de Janeiro State Government, Department of Education. (2022). *Curricular Organisation of Formative Itineraries*. Available from: Trails (educacao.rj.gov.br).

Table 37: Presence of the DP sciences learning outcome themes in BHSC Natural Sciences and Technology (NST)

Themes extracted from the learning outcomes of the DP sciences subject group	Presence in BHSC Natural Sciences and Technology (NST)	
1. Develop conceptual understanding and make connections		Presence can be inferred from the specific competencies and skills for BHSC NST, though there is less evidence of conceptual understanding or to making connections between science subjects.
2. Use and apply the knowledge, methods, tools, and techniques that characterise science		Present in the specific competencies and skills for BHSC NST, particularly competency 3.
3. Use creative and critical thinking (problem-solving, analysis, evaluation, synthesis)		Present in the specific competencies and skills for BHSC NST, many of which include problem solving, analysis, evaluation and synthesis.
4. Develop skills for scientific inquiry		Scientific inquiry is present in the specific competencies and skills for BHSC NST, though there is limited mention of specific experiments.
5. Develop technological skills		The development of technological skills is implied in the specific competencies and skills for BHSC NST.
6. Collaborate and communicate effectively		Communication skills are present in the specific competencies and skills for BHSC NST, though there is less mention of collaborative skills.
7. Be aware of global and local problems and the environmental, ethical, cultural, and social impact of science		Well-evidenced in the specific competencies and skills for BHSC NST, particularly competence 1.

Key:

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

Presence of the DP's Learning Outcome Themes

There is strong alignment between the learning outcomes of DP sciences and BHSC Natural Sciences and Technology (NST). Indeed, all DP learning outcomes themes for sciences are represented either completely or partially in the BHSC NST specific competencies and specific skills and are further evidenced in the additional skills for the formative itinerary (FI). The extent to which each DP theme is present in BHSC NST is discussed in more detail below.

1. Develop conceptual understanding and make connections

The ability to develop conceptual understanding and make connections is partially evidenced within BHSC NST. Indeed, the specific competencies include higher order skills such as analysis, synthesis and evaluation – all of which require strong conceptual understanding. With regards to making connections, there is evidence that this is expected between science subjects in BHSC NST. For instance, specific skill EM13CNT203 refers to evaluating and predicting the effects of interventions in an ecosystem on organisms, in respect to transformations of matter and energy.[145] This would require students to understand and relate

[145] Brazil, Ministry of Education. (2018). *5.3.1. Natural Sciences and Technology in High School: Specific competencies and skills.* BNCC.

knowledge within and between science subjects. The general competencies also include utilising knowledge from different areas, though this does not specifically refer to making connections between science subjects.

Furthermore, within the FI skills, conceptual understanding is also partially evident, as students are expected to identify and explain issues related to physical, chemical and/or biological phenomena. However, there are no explicit references to conceptual understanding, or to making connections between or within science subjects. In summary, as there are no explicit references to conceptual understanding or to making connections amongst science subjects, this DP theme is only partially present in BHSC NST.

2. Use and apply the knowledge, methods, tools, and techniques that characterise science

Using and applying the knowledge, methods, tools, and techniques that characterise science is evident across BHSC NST. The specific skills refer to using procedures and languages typical of natural sciences and of scientific investigation. It is likewise described that students should develop explanations, make predictions, interpret results, analyse models, theories and laws; and recognise the explanatory limits of science; which encompasses many elements of scientific study. This theme is further evidenced by specific skill EM13CNT301 which outlines how students will not only create hypotheses, use measuring instruments and generate data, but also justify the conclusions they reach from a scientific perspective.[146]

Moreover, multiple FI skills describe mobilising knowledge and resources related to Natural Sciences, which implies an application of scientific knowledge and methods. There is therefore strong evidence of this theme within BHSC NST.

3. Use creative and critical thinking (problem-solving, analysis, evaluation, synthesis)

The DP theme of creativity and critical thinking is evident within BHSC NST. For example, students are expected to propose appropriate solutions to identified problems, whilst considering local and global contexts. Moreover, students are expected to evaluate the applications of scientific knowledge, analyse natural phenomena, recognise the explanatory limits of science, and to build strategies for selecting reliable sources of information such that they can evaluate and justify conclusions.

Additionally, within the FI skills, students are expected to utilise creative resources related to Natural Sciences to solve real environmental and societal problems, exploring and contrasting different sources of information. As such, there is evidence that problem solving, analysis, evaluation and synthesis are present in BHSC NST. However, it can be noted that the DP places more emphasis on evaluation, particularly on the evaluation of experimental procedures.

4. Develop skills of scientific inquiry

The DP theme of applying skills to conduct insightful investigations is present within BHSC NST. As described previously, BHSC NST refers to using procedures and languages typical of Natural Sciences, and of scientific investigation. Students are expected to investigate issues, and more specifically students should be able to: come up with questions, hypotheses, predictions and estimates; use measuring instruments; represent and interpret models, data

[146] Ibid.

and experimental results; as well as to evaluate and justify conclusions.[147] Ethical considerations are also referred to in general, and it can be inferred that this would be applied to conducting investigations.

Furthermore, the FI skills include taking part in a project involving the formulation of concrete proposals, which is suggestive of planning and organising an investigation. There are no specific references to experimental procedure, but it is implied that students will be able to carry out investigations.

There is therefore overall strong evidence of scientific investigation in BHSC NST. However, the DP science curriculum includes a greater amount of detail with regards to the specific experiments and procedures that students should be aware of, which is not the case for the BHSC NST.

5. Develop technological skills

There is clear evidence that the DP theme of developing technological skills is present in BHSC NST. It is described that students should be able to use and communicate through different technologies and evaluate their applications. Moreover, BHSC NST refers to students using digital devices in many different contexts and areas of science. In addition, the FI skills include multiple skills that require students to consider available technologies when proposing solutions to real problems. As such, it is clear that students are required to develop technology skills in a scientific context in BHSC NST.

6. Collaborate and communicate effectively

The DP's theme of effective communication is evident in BHSC NST, as students are expected to communicate to varied audiences and in different contexts. Multiple specific competencies also refer to participating in debate, from which communication skills such as expressing arguments or ideas can be inferred. Moreover, interpreting information from varied sources, distinguishing between different points of view, as well as expressing conclusions are included – all of which relate to effective communication.

There is less evidence of collaborative skills in BHSC NST. However, general competencies for high school education in the BHSC refer to exercising cooperation and respect for others, which is suggestive of collaboration. Moreover, as mentioned previously, the FI skills refer to students taking part in a project, which would potentially involve elements of individual or group work. Overall, as collaboration does not seem to be an explicit focus, this theme is partially evidenced in BHSC NST.

7. Be aware of global and local problems and the environmental, ethical, cultural, and social impact of science

The DP's theme regarding awareness of global and local problems and the environmental, ethical, cultural, and social impact of science is evident in BHSC NST. Indeed, BHSC NST expects students to demonstrate an awareness of prominent issues within science as they participate in and/or promote debates in topics of scientific relevance. Awareness of identified problems among the more local context of Brazilian society is likewise shown, as well as

[147] Brazil, Ministry of Education. (2018). *5.3.1. Natural Sciences and Technology in High School: Specific competencies and skills.* BNCC.

knowledge of the contemporary experiences and challenges of young people. Furthermore, there are multiple references made to the social, cultural, and environmental impacts of science. There are fewer references to the ethical impact of science, though students must debate using ethical and responsible arguments, as well as discuss the misuse of knowledge from Natural Sciences.

Moreover, the FI skills describe that students demonstrate their ability to identify and explain sociocultural and environmental issues and to solve real environmental and societal problems which, although not specified, is suggestive of an awareness of issues that are present in either the local or global context. Students must also evaluate how knowledge and resources related to natural science can be used and the socioenvironmental impacts of this. Overall, there is therefore strong evidence of the DP theme in BHSC NST.

Other Themes in BHSC NST Learning Outcomes

Most of the themes and skills described BHSC NST are in the DP; however, it can be noted that there are few aspects that are highlighted more specifically.

Indeed, the BHSC learning outcomes specifically highlight that students will learn the historic contextualisation of scientific discoveries and discuss models, theories and laws proposed in different times. The DP learning outcomes do not specifically identify historical context of scientific discoveries; however, teachers may explore these with students during the course. In addition, the BHSC NST learning outcomes specifically highlight that students should learn about the *misuse* of knowledge regarding natural science in different social and historical contexts. While misuse of knowledge is not specifically mentioned in the DP learning outcomes, considering the impact of scientific knowledge is a key theme and this will likely include exploring negative impacts and unethical practices.

Furthermore, BHSC NST learning outcomes include a larger emphasis on the engagement with scientific literature than the DP sciences learning outcomes. For example, the specific skill EM13CNT303 and the FI skill EMIFCNT03 each state that students should interpret scientific texts.[148] The latter specifies that students should be able to select information from scientific texts such as studies and/or research (bibliographic, exploratory, field, experimental, etc.). The DP does refer to the ability to analyse, evaluate and synthesize scientific information and claims, but does not make specific reference to engaging with scientific texts. The extended essay (EE) in the DP core would provide opportunity for a similar engagement with literature as part of the high-level research. Although EE may be focused on subjects other than science. Likewise, scientific texts may be reviewed as part of the DP's internally assessed science investigation. Therefore, there is scope for students to engage with scientific literature in the DP curriculum, but there is less emphasis specifically on literature within the learning outcomes for science.

Summary

Overall, there is strong alignment between DP sciences and BHSC NST with regards to learning outcomes. The DP learning outcome themes of applying the elements that characterise science, using creativity and critical thinking, developing technological skills, and being aware of the issues and impacts of science, are all evident in BHSC NST. However,

[148] Brazil, Ministry of Education. (n.d.). *Curricular References for the Preparation of Formative Itineraries*. p. 11.

there is less emphasis on making connections between and within science subjects and collaboration in BHSC NST than the DP. Moreover, although scientific investigation is present in BHSC NST, there is less detail regarding the specific experiments and experimental skills compared to the DP.

4.10.2 Content

This section compares and contrasts the biology content of DP biology and BHSC NST. For the content analysis of BHSC NST, several sources are used. For BHSC NST (BGE), the BNCC's specific competencies and specific skills for NST have been used, as well as the Rio de Janeiro Referential Curriculum (RJRC) for biology in basic general education. For the analysis of BHSC NST (FI), Rio de Janeiro's specialisation pathways for Natural Sciences and Technology formative itineraries have been used. The biology content from the BNCC and RJRC are presented in the following diagrams.

Figure 21: Visualiser of BHSC Natural Sciences and Technology. (Source - BNCC).

Natural Sciences and Technology		
Specific Competencies		
1. Analyse natural phenomena and technological processes, based on the interactions and relationships between matter and energy, to propose individual actions and collective actions that improve production processes, minimize impacts on and improve living conditions at the local, regional and global level.	2. Analyse and use interpretations of the dynamics of Life, the Earth and the Cosmos to elaborate arguments, make predictions about the functioning and the evolution of living beings and the Universe, and to ground and defend ethical and responsible decisions.	3. Investigate problem situations and evaluate applications of scientific knowledge and its implications in the world, using procedures and languages of the Natural Sciences, in order to propose solutions that consider local, regional and/or global demands, and communicate their findings and conclusions to a variety of audiences, in a variety of contexts and through different media and digital information technologies and communication (TDIC).
Specific Skills*		
EM13CNT101 - EM13CNT107	EM13CNT201 - EM13CNT209	EM13CNT301 - EM13CNT310

* See Appendix D for the Natural Sciences and Technology Specific Skills in full detail.

Figure 22: Visualiser of BHSC Natural Sciences and Technology. (Source - RJRC).

Basic General Education	Formative Itinerary		
Biology (based on the BNCC and organised using the Specific Competencies and Skills)	**Integrated Core**	**Specialisation Pathways for Natural Sciences and Technology**	
	Life Project	**Energy Solutions**	**Natural Resources**
	Elective 1	Energy and its transformations	Consumption, multiple uses and management
	Elective 2	Energy, environmental impacts, and sustainability	Diversified sustainable practices
	Elective 3 (chosen from Catalogues, such as the Catalogue of Electives for Natural Sciences and Technology)	Energy: Problematisation and awareness raising	Natural resources and sustainable development

4.10.2.1 Structure

Science in the DP is structured such that physics, chemistry and biology are separate subjects, each with their own distinct content. In contrast, the BHSC combines physics, chemistry, and biology into Natural Sciences and Technology (NST). Where DP students choose one science subject to study at either SL or HL, Brazilian high school students study all sciences as part of NST in basic general education (BGE), and then can choose to specialise in NST in their formative itinerary (FI). As such, unlike the offering of DP biology HL, the BHSC does not offer an option to specialise in biology specifically. Moreover, DP science subjects are studied over the two-year programme, whereas science subjects may be taught in any or all years of high school in Brazil.

DP biology content is arranged into four conceptual themes – A. Unity and diversity, B. Form and function, C. Interaction and interdependence, and D. Continuity and change. There are four levels within with each theme, namely 1. Molecules, 2. Cells, 3. Organisms, and 4. Ecosystems.

In contrast, BHSC NST (BGE) content is not organised using biology topics. Indeed, the BNCC articulates specific competencies and skills for NST that are an integration of skills and physics, chemistry, and biology content. Each state in Brazil can decide how to organise their curriculum to ensure that the NST specific competencies and skills are taught in basic general education. For example, the Rio de Janeiro's Referential Curriculum (RJRC) organises basic general education into distinct subjects, with biology being one of these. The RJRC then organises its biology content using the NST specific competencies and specific skills and adds topics that should be linked with these.

Content for BHSC NST (FI) is developed by each Brazilian state and combines physics, chemistry, and biology content. As an example, the RJRC organises NST formative itinerary content into two specialisation pathways, namely 'Natural Resources' and 'Energy Solutions', each of which is made up of three curricular components. [149]

4.10.2.2 Content Alignment

This section will analyse the alignment of biology content in DP biology and BHSC NST. The following tables present a simplified summary of the extent of content alignment that BHSC NST (BGE) and BHSC NST (FI) have at the topic level with DP biology.

[149] Rio de Janeiro State Government, Department of Education. (2022). *Curricular Organisation of Formative Itineraries*.

Table 38: Summary of the content alignment BHSC NST has with the main themes in DP biology.

DP biology themes and levels	BHSC NST (BGE)		BHSC NST (FI)*	
	SL presence	AHL presence	SL presence	AHL presence
A Unity and diversity				
A1 Molecules				
A2 Cells				
A3 Organisms				
A4 Ecosystems			**	
B Form and function				
B1 Molecules			**	
B2 Cells				
B3 Organisms				
B4 Ecosystems		N/A	**	N/A
C Interaction and interdependence				
C1 Molecules			**	
C2 Cells				
C3 Organisms				
C4 Ecosystems		N/A	**	N/A
D Continuity and change				
D1 Molecules				
D2 Cells				
D3 Organisms				
D4 Ecosystems			**	
Experimental programme				

Key:

	Strong presence of this topic in BHSC NST		*Partial presence of this topic in BHSC NST, or the extent of presence is unclear*		*Little or no presence of this topic in BHSC NST*

***** Content alignments found for basic general education (BGE) are carried forwards and combined with, where applicable, new alignments identified in the formative itinerary (FI), to represent the cumulative content covered.
** The documentation indicates that the formative itinerary includes some similar content from this DP topic.

BHSC Natural Sciences and Technology (Basic General Education) - BHSC NST (BGE)

BHSC NST (BGE) covers some SL content from most levels in the DP biology themes. There is generally little to no presence of DP AHL content in BHSC NST (BGE).

It should be noted that, where partial presence has been concluded, this is often based on an assumption that the broadly-described topics for BHSC NST (BGE) can be expected to contain similar content. Thus, the actual degree of alignment may differ to what a judgement of 'partial presence' suggests. The following discusses the presence of each DP biology theme in BHSC NST (BGE) in more detail.

A. Unity and diversity

BHSC NST (BGE) has some alignment with SL content within A. Unity and diversity, with the exception of A3. Organisms. Indeed, it can be inferred that SL content from A1.1 Water may be covered within 'origin of life', but the properties of water and its relationship to organisms is not explicitly evident. Moreover, topics of biological inheritance and biomolecules reflect coverage of SL content from A1.2. Nucleic acids. More specifically, the structure of amino acids, proteins, DNA and RNA are included within BHSC NST (BGE).[150] Furthermore, 'cellular

[150] These topics are drawn from the RJRC.

organisation' in the BHSC NST (BGE) likely includes similar content to A2.2 Cell structure – though, notably, there are no references to microscopy. Additionally, SL content from A4.1 Evolution and speciation and A4.2 Conservation of biodiversity is likely present within BHSC NST (BGE) topics of 'evolution', 'origin and extinction of species', and 'biodiversity'. Finally, without references to specific concepts such as genomes, it is less reasonable to infer the presence of SL content relating to A3.1 Diversity of organisms in BHSC NST (BGE).

The topics of exobiology, phylogeny and phylogenetic trees reflect some AHL content from A1.1 Water and A3.2 Classification and cladistics could be covered.[151] Overall, however, there is little indication that AHL content from A. Unity and diversity is covered in BHSC NST (BGE) and its presence cannot be reasonably assumed from the broad references in BHSC NST (BGE) documentation.

B: Form and function

BHSC NST (BGE) has partial alignment with SL content from the theme B. Form and function at the level of B1. Molecules and B4. Ecosystems, but there is limited evidence of SL content from B2. Cells and B3. Organisms. Indeed, SL content from B1.1 Carbohydrates and lipids and B1.2 Proteins is evident within BHSC NST (BGE), based on the topics ‘biomolecules’ and ‘the structure and properties of organic compounds’. There is also reference to carbohydrates, lipids and proteins (although notably this is part of chemistry content).[152] Moreover, the structure of amino acids, DNA and RNA are also present in BHSC NST (BGE).[153] SL content from B4.1 Adaptation to the environment and B4.2 Ecological niches is likely encompassed within BHSC NST (BGE) in the topic of ‘ecosystems’. The topics of ‘photosynthesis and photosynthetic organisms’ and ‘chemosynthesis’ also indicate inclusion of content from the latter topic.[154] There is little evidence that SL content relating to B2. Cells and C3. Organisms is included, and their presence cannot be inferred from the broad references to ‘cellular organisation’ in BHSC NST (BGE).

There is little evidence that AHL content from B. Form and function is covered in BHSC NST (BGE), and its presence cannot be reasonably inferred from the general areas referenced in documentation.

C: Interaction and interdependence

BHSC NST (BGE) has some alignment with SL content in C. Interaction and interdependence. There is limited evidence that SL content from C1.1 Enzymes and metabolism is included, as there are no references to enzymes or to metabolism in BHSC NST (BGE). The presence of SL content in C1.2 Cell respiration and to C1.3 Photosynthesis is indicated by the references to cellular respiration and photosynthesis in BHSC NST (BGE). Moreover, it is indicated that SL content from C2.2 Neural signalling is included within BHSC NST (BGE) as it includes neuroscience and electrical impulses in neurones.[155] Some SL content from C3.1 Integration of body systems is likely to be included in BHSC NST (BGE) because the latter includes ‘bodies’ and ‘organs and organ systems’. Likewise, some SL content from C3.2 Defence against disease is likely to be included in BHSC NST (BGE) as ‘epidemiological processes’

[151] The topics have been drawn from the RJRC.
[152] Ibid.
[153] Ibid.
[154] Ibid.
[155] The latter topic has been drawn from the RJRC.

are referenced. Furthermore, BHSC NST (BGE) includes 'vaccination', 'individual and collective health' and 'sexually transmitted diseases'.[156] SL content in C4.1 Populations and communities is likely encompassed by BHSC NST (BGE), which includes references to 'populations' and 'ecosystems'. SL content from C4.2 Transfers of energy and matter is also indicated as BHSC NST (BGE) includes biogeochemical cycles and food webs, as well as autotrophic and heterotrophic energetic processes.[157]

There are few indications that AHL content from C. Interaction and interdependence is included in BHSC NST (BGE), and its presence cannot be reasonably inferred from the broad areas described in the documentation.

D. Continuity and change

There is limited evidence to suggest that SL content from D1.1 DNA replication and D1.2 Protein synthesis is included within BHSC NST (BGE) as there are no references to specific concepts such as transcription. Similarly, SL content from D2.1 Cell and nuclear division cannot be inferred without further reference to concepts such as mitosis, meiosis or cytokinesis. SL content in D4.1 Natural selection is likewise not evident in BHSC NST (BGE), as there are no references to concepts such as competition or selection pressures. Some coverage of D1.3 Mutations and gene editing in BHSC NST (BGE) is indicated through reference to 'mutations'. There are no references to water potential, homeostasis or feedback loops to indicate that SL content from D2.3 Water potential and D3.3 Homeostasis is present BHSC NST (BGE). SL content from D3.1 Reproduction and D3.2 Inheritance is likely present as BHSC NST (BGE) includes 'reproduction' and 'biological inheritance'. D4.2 Sustainability and change is indicated in BHSC NST (BGE) as sustainability, deforestation, bioaccumulation and ecosystem balance are referenced.[158] D4.3 Climate change can similarly be inferred, as BHSC NST (BGE) includes global warming and references climate change directly.[159]

Overall, however, there is little indication that AHL content from D. Continuity and change is covered in BHSC NST (BGE), particularly as much of the content goes beyond what can be reasonably inferred from the broad references in the documentation.

Experimental programme

BHSC NST (BGE) includes students conducting investigations into real-world problems using scientific procedures. Further general competencies are suggestive of planning skills such as developing hypotheses or reaching conclusions and mention laboratory skills such as employing tools. There are also references to examining models, simulations, and prototypes. There are, therefore, some similarities to the DP's experimental programme. However, BHSC NST (BGE) does not detail the specific experiments to be conducted, nor the specific practical skills to be developed. Furthermore, there is no inclusion of anything similar to the DP's collaborative sciences project. As such, it is concluded that BHSC NST (BGE) partially aligns with this component of the DP biology syllabus.

[156] These topics are drawn from the RJRC.
[157] The last two topics are drawn from the RJRC.
[158] Most of these topics are drawn from the RJRC.
[159] The latter topic is drawn from the RJRC.

Other BHSC NST (BGE) Content

There is some biology content in BHSC NST (BGE) that is not present in DP biology, see the following table:

*Table 39: Biology content in BHSC NST (BGE) which is not covered in the DP.**

Significant content which is not included in DP biology
• Environmental policies • Public health

Environmental policies and political considerations feature within BHSC NST (BGE). For instance, students are expected to evaluate the effects of environmental policies and consider political issues in relation to the world's energy needs. Political considerations such as these do not feature in DP biology.

BHSC NST (BGE) includes considerations of infrastructure and basic services such as health care as well as epidemiological processes (the study of the determinants of health and disease). Whilst this may feature in the DP biology topic of vaccination, the area is likely explored in less detail and with less focus on things such as public awareness and education.

Summary

Overall, BHSC NST (BGE) includes some SL content from each of the DP biology themes at most levels. However, SL content from various levels across three of the DP biology themes is not evident – namely A3. Organisms, B3. Organisms, B4. Ecosystems, D1. Molecules, and D2. Cells. The absence of these areas within BHSC NST (BGE) suggests that its biology content has a lower breadth of content in comparison to DP biology. As the coverage of specific biology concepts is often inferred from broad references in the documentation, it cannot be confidently concluded that the depth of biology content in BHSC NST (BGE) is similar to that of DP biology SL. Indeed, the absence of references to specific concepts in BHSC NST (BGE) may indicate that biology topics are not studied to the same degree of depth as DP SL. Lastly, there is very little presence of AHL biology content within BHSC NST (BGE), thus it has a lesser breadth and depth than DP biology HL.

BHSC Natural Sciences and Technology (Formative Itinerary) – BHSC NST (FI)

The primary way high school students can further pursue science is by choosing to specialise in Natural Sciences and Technology in their formative itinerary. The Rio de Janeiro specialisation pathways for NST formative itineraries were consulted to provide examples of the types of content covered in BHSC NST (FI).

The specialisation pathways indicate that some SL content from the following may be included in BHSC NST (FI): A4. Ecosystems, B2. Molecules, B4. Ecosystems, C1. Molecules, C4. Ecosystems, and D4. Ecosystems. No other SL or AHL content could be identified in the specialisation pathways. This can be attributed to the focus of the formative itinerary component on a particular real-world issue or context, and the emphasis on application of knowledge as opposed to introducing additional content.

Table 40: Biology content in BHSC NST (FI) which is not covered in the DP.

Significant content which is not included in DP biology
There is no additional significant biology content in BHSC NST (FI) that is not included in the DP.

Summary

In conclusion, while formative itineraries are developed by each state, the examples from Rio de Janeiro provide useful insights into the content that these may cover and how this aligns with DP biology. Overall, the content of BHSC NST (FI) does not appear to present a stronger alignment with DP biology content than BHSC NST (BGE), as very few further SL topics and AHL topics could be identified. Instead, BHSC NST (FI) provides an opportunity for students to extensively apply biology (and other science) concepts to a variety of contexts and issues, such as renewable energy sources and sustainable resource consumption. Therefore, the breadth and depth of biology content covered in BHSC NST (FI) is less than that of DP biology HL. The breadth in comparison to DP SL may be similar and, as mentioned previously, the depth cannot be confidently ascertained due to the lesser amount of detail in the documentation.

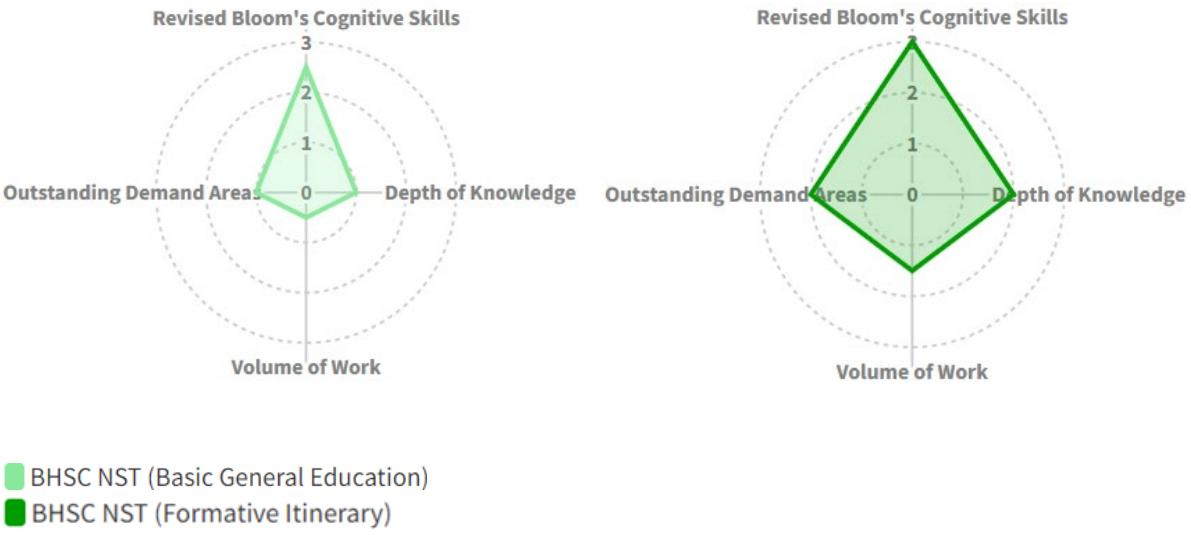
4.10.3 Demand

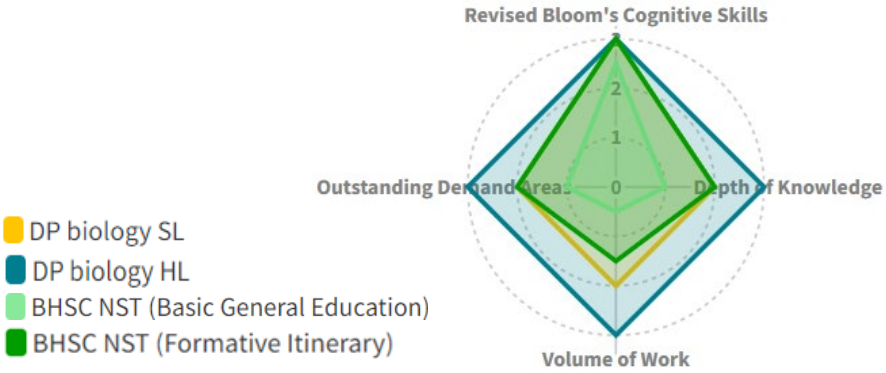
This section considers the alignment between DP biology and BHSC NST in terms of demand. Using the same demand tool for the analysis of each subject, a demand profile was created for DP biology (SL and HL), BHSC NST (BGE), and BHSC NST (FI).

BHSC NST (BGE) represents the demand of biology in basic general education. BHSC NST (FI) represents the cumulative demand of studying biology in basic general education and then specialising in an NST formative itinerary. It should be noted that the scores reflect the demand of the whole NST formative itinerary component, rather than its biology content specifically.

These demand profiles are presented in the form of radar diagrams, with a superimposed diagram featured to enable the immediate visual comparison of all profiles.

Figure 23: Visual representations of subject demand





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**:
  - Both DP biology SL and HL received a score of 3.
  - BHSC NST (BGE) was awarded a score of 2.5, as the learning outcomes have a predominant focus on analysis, with some evidence of evaluation and creation/synthesis focused goals (for instance, creating and/or interpreting equations). However, there is insufficient evidence of a strong presence of evaluation and synthesis to warrant a judgement of 3. For BHSC NST (FI), a score of 3 was awarded due to a predominant focus on synthesis, creation and analysis in the skill for NST formative itineraries. Indeed, the formative itinerary component allows for the synthesis of knowledge across science topics, finding innovative approaches to real world issues and project-based work, all of which suggest higher order thinking, warranting a judgement of 3.

- Regarding the score for **Depth of Knowledge**:
  - DP biology SL received a score of 2 and DP biology HL received a score of 3.
  - BHSC NST (BGE) was awarded a score of 1 for depth of knowledge. As is the case for other science subjects, the learning outcomes indicate higher order skills (such as making predictions, performing calculations and interpreting results). However, the extent of depth to which biology topics are explored is unable to be confirmed from the broad references used in the documentation. As such, whilst there is potential for some topics to be studied in-depth and require complex reasoning, there is insufficient evidence to warrant a judgment of 2. For BHSC NST (FI), depth of knowledge was judged to merit a score of 2. This was the case because the open ended, project-based nature of this course, as well as its contextualisation in the real world, are suggestive of higher order processing. However, as BHSC NST (FI) does not appear to cover complex science topics, a score of 2, rather than 3, was awarded.

- Regarding the scores for **Volume of Work**:
  - DP biology SL received a score of 2 for a moderate-heavy workload and DP biology HL received a score of 3 for a heavy workload.

  - BHSC NST (BGE) was awarded a score of 0.5. As with other science subjects, the complexity of the concepts being covered can be uncertain due to the limited detail provided. However, the majority of biology content can be assumed to be more basic than complex. Indeed, there is very limited evidence for a substantial number of complex subtopics and concepts. Therefore, it was decided that there was a generous time allocation[160] per theme and that this overall represented a light volume of work. For BHSC NST (FI), a score of 1.5 was given. The course has scope for a significant proportion of the time to be spent on issues beyond basic conceptual depth, and the potential for in depth project-based work. Based upon the time allocated to the specialisation component of formative itineraries, the time allocation per theme was judged to be standard. However, the complexity of the content explored is unclear, and may be largely at teacher's discretion. Therefore, the judgement is limited to a 1.5.

- Regarding the scores for **Outstanding Areas of Subject Demand**:
  - DP biology SL received a score of 2 and DP biology HL received a score of 3.
  - BHSC NST (BGE) was given a score of 1 for outstanding areas of demand as the inclusion of debates, real world applications and the investigative approaches were considered to potentially allow for 1 to 2 stretch areas. For BHSC NST (FI), a score of 2 was awarded. The emphasis on the following provided further stretch areas: real-life application, the project-based work, the cross curricular nature of the course, and the opportunities for discussion and debate.

[160] Time allocations were drawn from the RJRC.

4.11 Mexico

Education in Mexico is overseen by the Secretariat of Public Education and is compulsory from the age of three to 18. The school system is divided into primary school (ages six to 11) and secondary school (ages 11 to 18). Secondary education in Mexico is divided into lower and upper secondary, each lasting three years.

Upper secondary (*Educación Media Superior)* is offered through three main pathways:

- *Bachillerato General*
- *Bachillerato Tecnológico*
- *Educación Profesional Técnica.*

The Mexican *Bachillerato General* (MBG) is a traditional, academic pathway designed to prepare students for higher education, as well as developing the competencies necessary for the world of work.[161] The *Bachillerato Tecnológico*, combines general and vocational education to enable students to pursue higher education or a more professional/technical route.[162] Finally, the *Educación Profesional Técnica* is purely vocational and provides access to the labour market and employment.[163] Within the *Educación Media Superior,* the MBG is the focus in this report, as this programme is the most aligned with the DP.

The MBG lasts for three years and is divided into six semesters, with each year consisting of two semesters. During the MBG, students complete five curriculum components, namely the:

- Core component (‘*Componente de Formación Fundamental’*)
- Mandatory Extended Core component *(‘Componente de Formación Fundamental Extendido Obligatorio’*)
- Extended Core component *(‘Componente de Formación Fundamental Extendido’*)
- Work Experience component *(‘Componente de Formación Laboral’*)
- Expanded Curriculum *(‘Currículum Ampliado’*).[164]

Students study units from all five of these components. Units in the Core, Mandatory Extended Core, and Extended Core components are organised into Socio-cognitive Resources and Areas of Knowledge, which are outlined below:

Socio-cognitive Resources:

- Language and Communication
- Mathematical Thinking
- Historical Consciousness
- Digital Culture

Areas of Knowledge:

- Natural Sciences, Experimental Sciences and Technology
- Social Sciences
- Humanities

The MBG units used for comparison to DP biology are outlined below.

[161] Government of Mexico. (n.d.) *Bachillerato General.* Available from: Bachillerato General (sep.gob.mx)
[162] Mexican Secretariat of Education, Science, Technology and Innovation. (2024). *Bachillerato Tecnológico*. Available from: Bachillerato Tecnológico | Secretaría de Educación, Ciencia, Tecnología e Innovación (edomex.gob.mx)
[163] Government of Mexico. (n.d.). *Servicios educativos*. Available from: Subsecretaría de Educación Media Superior: Servicios educativos (sep.gob.mx)
[164] Mexican Secretariat of Public Education. (2024). *Base Document for the Bachillerato General*.

Natural Sciences, Experimental Sciences and Technology[165]

Natural Sciences, Experimental Sciences and Technology is one of the four Areas of Knowledge articulated in the Common Curriculum Framework for Higher Secondary Education in Mexico and includes common learning for all high school students. This area is described as referring to human activities and the study of the natural world. In addition to studying these areas, students formulate and verify hypotheses, raise questions and search for answers related to the processes and dynamics of natural phenomena. Some of the units within the Natural Sciences, Experimental Sciences and Technology knowledge area are compulsory for all MBG students and some are optional.

Compulsory *Natural Sciences, Experimental Sciences and Technology units in the MBG:*

There are six compulsory units in the Core curriculum component. These are designed in a transversal way; therefore each one contains elements of all the science disciplines.

- **Matter and its interactions**[166]

This unit is taught in the first semester of the MBG and provides foundational knowledge of scientific concepts. Content includes elements, molecules, microscopic structure, the water cycle and temperature changes within chemical reactions.

- **Conservation of energy and its interactions with matter**[167]

This unit is taught in the second semester of the MBG, and whilst it builds on some concepts covered in the Matter and its interactions, it is also aimed at providing a foundational knowledge of scientific concepts. Content includes different types of energy and energy transfers, electromagnetic fields, changes of state, and the energy in chemical reactions.

- **Ecosystems: interactions, energy and dynamics**[168]

This unit is taught in the third semester of the MBG and contains fundamental areas of science but has a greater focus on biology than the previous units. Content includes cells, photosynthesis and respiration, the carbon cycle, food webs and ecosystems.

- **Chemical reactions: conservation of matter in the formation of new substances**[169]

This unit is taught in the fourth semester of the MBG and is designed to build on the content studied within the 'matter and its interactions' unit by providing more depth and detail. Content includes chemical reactions, exothermic and endothermic reactions, atomic structure, the periodic table and nuclear reactions.

[165] Mexican Secretariat of Public Education. (2024). *Base Document for Bachillerato General.*
[166] Mexican Secretariat of Public Education. (2023). *Programme of Knowledge Area Studies in Matter and its Interactions.* Available from*:* Undersecretariat of Higher Secondary Education : Proposal for the Common Curricular Framework for Upper Secondary Education (sep.gob.mx)
[167] Mexican Secretariat of Public Education. (2023). *Programme of Knowledge Area studies in Conservation of energy in its interactions with matter.*
[168] Mexican Secretariat of Public Education. (2023). *Programme of Knowledge Area studies in Ecosystems: interactions, energy and dynamics.*
[169] Mexican Secretariat of Public Education. (2023). *Programme of Knowledge Area studies in Chemical reactions: conservation of matter in the formation of new substances.*

- **Energy in the processes of daily life**[170]

This unit is taught in the fifth semester of the MBG and builds on the knowledge acquired through previous units. This unit focuses on how energy is linked to the real world and how understanding it helps students to make sense of phenomena in their day-to-day lives. Content includes forces, motion, momentum, Newton's laws, moments, magnetic fields and electricity.

- **Organisms: structures and processes. Inheritance and biological evolution**[171]

This unit is taught in semester six of the MBG and builds biology and chemistry content from previous units. Content includes specialised cells, reproduction, variation, inheritance, natural selection, adaptation, evolution and protein synthesis.

There are also three compulsory units within the Mandatory Extended Core component.

- **Science Workshop I**[172]

  This unit is taught in the second semester and weaves together the overarching concepts from other units. However, within Science Workshop I there is more focus on practical work and experimental activities. These include designing models, formulating questions and hypotheses and proposing solutions to problems within the students' environment.

- *Science Workshop II*
- *Space and Society*

  At the time of writing this report, there is currently no publicly available documentation for the MBG units Science Workshop II and Space and Society.

Optional *Natural Sciences, Experimental Sciences and Technology units in the MBG:*[173]

- **Selected Topics in Biology I**
- **Selected Topics in Biology II**

The optional units listed above are part of the Extended Core component and, if chosen, are studied in the last two semesters of high school. Students of the MBG choose eight optional units, typically four pairs, from a range of Areas of Knowledge and Socio-cognitive Resources, and therefore the optional units studied will vary between students.

The analysis will consider, and distinguish between, Natural Sciences, Experimental Sciences and Technology units which are compulsory in the MBG, and those which are optional.

[170] Mexican Secretariat of Public Education. (2023). *Programme of Knowledge Area studies in Energy in the processes of daily life.*
[171] Mexican Secretariat of Public Education. (2023). *Programme of Knowledge Area studies in Organisms: structure and processes. Inheritance and biological evolution.*
[172] Mexican Secretariat of Public Education. (2024). *Programme of the UAC of the Knowledge Area Science Workshop I.*
[173] Undersecretary of Higher Secondary Education. (2018). *Programs of Study for the Class of 2022 – 2025. Propaedeutic Training Component.* Available from: Programs of Study for the Generation 2023 - 2026 and Subsequent. (sep.gob.mx)

4.11.1 Learning Outcomes

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

The learning outcome themes for all DP science subjects 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. Likewise, the MBG articulates learning outcomes that are applicable to all sciences, and these are currently presented as Learning Progressions and Extended Disciplinary Competencies. Where relevant, General Competencies for the MBG have also been considered.

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 MBG curricula.

Table 41: Presence of the DP sciences subject group learning outcome themes in the MBG

Themes extracted from the learning outcomes of the DP sciences subject group	Presence in the Bachillerato General	
1. Conceptual understanding and making connections		Strongly present in Learning Progressions, General Competences and Extended Disciplinary Competences.
2. Use and application of knowledge, methods, tools, and techniques that characterise science		Strongly present in Learning Progressions, General Competences and Extended Disciplinary Competences.
3. Creativity and critical thinking (problem-solving, analysis, evaluation, synthesis)		Strongly present in the Learning Progressions, General Competences and Extended Disciplinary Competences.
4. Apply skills necessary to carry out insightful and ethical investigations (planning, collecting data, organising, following ethical guidelines)		Strongly present in the Learning Progressions, General Competences and Extended Disciplinary Competences.
5. Development of technological skills		Present in the Learning Progressions, General Competences and Extended Disciplinary Competences.
6. Effective collaboration and communication		Strongly present in the Learning Progressions, and General Competences.
7. Awareness of global and local problems and the environmental, ethical, cultural, and social impact of science		Not particularly evident in the Learning Progressions, however, strongly present in the General Competences and Extended Disciplinary Competences.

Key:

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

<u>Presence of the DP's Learning Outcome Themes</u>

As can be seen in Table 41, there is strong alignment between the DP learning outcome themes and the Mexico curricula. All DP learning outcome themes are found within many

areas of the Mexico curricula, although some are more strongly and widely emphasised than others. Below, the extent to which each theme is present in the MBG is discussed in more detail.

1. Conceptual understanding and making connections

There is strong evidence of the DP's theme of making connections and developing conceptual understanding within the MBG. For compulsory units, the Learning Progressions describe 'Science and Engineering Practices', where students are drawing on different sources of information and then comparing them with what they learn in the classroom. The fundamentals of Science Workshop I also highlight the importance of this theme through the discussion of how students will reflect on the relationship between science, technology and the context in which they are covering different concepts.

For the optional units, the General Competences also include this theme through requiring students to express ideas and concepts, articulate knowledge from various fields, and establish relationships between them and their daily life. Finally, the Extended Disciplinary Competences expect students to carry out interdisciplinary projects, which further strengthens the presence of this theme.

2. Use and application of knowledge, methods, tools, and techniques that characterise science

The DP's theme of knowledge, methods, tools and techniques that characterise science encompasses different aspects, and therefore parts of it can be found in different places; these various parts taken as a whole result in this theme being strongly present in the MBG. For compulsory units, the Science and Engineering Practices state that students will collect evidence and then explain phenomena based on this evidence. It goes further to stipulate that this evidence is consistent with the ideas and theories of science. Science Workshop I aims to promote skills such as observation, experimentation and problem solving.

Regarding optional units, the General Competences cover this theme well, as they require students to follow instructions and procedures reflectively, understanding how each step contributes to achieving an objective. Students are also expected to build hypotheses, design, and then apply models to test the validity of these hypotheses. Furthermore, it is outlined that students will synthesise the evidence they obtain through experiments to produce conclusions and formulate new questions. The Experimental Sciences Extended Disciplinary Competences also illustrate this theme by outlining a requirement for students to use specialised tools and equipment, and handling substances and equipment appropriately and safely.

3. Creativity and critical thinking (problem-solving, analysis, evaluation, synthesis)

The DP's theme of using critical thinking, particularly analysis and synthesis, is strongly reflected within the Mexico curricula. For compulsory units, students are expected to formulate, refine and evaluate problems, evaluate information and its reliability and make evidence-based decisions from a critical standpoint. Skills highlighted in Science Workshop I include observation, experimentation and problem-solving, as well as the aim of encouraging students' capacity for logical thinking. The transversal relationships in the Corecurriculum component emphasise the importance of students' critical thinking and their ability to reflect, discuss, contrast and investigate information.

The General Competences require students to choose between sources of information and discriminate between them based on their relevance and reliability; thereby requiring students to analyse and evaluate different texts or data sets. This theme is also present in the General Competences, where students are expected to synthesise evidence, evaluate arguments, critically and responsibly assess benefits and risks and evaluate the implications of the use of science and technology. Problem-solving is also an aspect that is present through the Mexico curricula and mentioned repeatedly in various areas through references to students proposing ways to solve a problem and defining a course of action with specific steps. This also encompasses the creativity aspect of this DP theme through the focus on students designing prototypes or models in order to solve problems.

4. Apply skills necessary to carry out insightful and ethical investigations

There are many references in the Mexico curricula to skills involving investigations, such as the descriptions within the Science and Engineering Practices where students are required to develop skills of planning and conducting research, searching for information to use as evidence for carrying out planned investigations. There is also a statement referring to the analysis and interpretation of data, followed by reference to students building explanations and designing solutions. The introduction to the Science Workshop I unit mentions practical work, and describes the promotion of observation, experimentation and problem-solving skills. Another compulsory unit, Science Workshop II, is likely to contain further evidence of practical work; however, at the time of writing, this unit was not publicly available for review.

For optional units, the General Competences detail scientific investigations more clearly through statements describing how students will build hypotheses and design and apply models to test their validity, as well as the synthesis of evidence obtained through experimentation to produce conclusions and formulate new questions. The Extended Disciplinary Competences of the Experimental Sciences show the presence of this theme through the description of students using specialised tools and equipment and applying the appropriate health and safety techniques to practical work in order to minimise risk. Therefore, overall, there is strong presence of this DP theme in the Mexico curricula.

5. Development of technological skills

Technology skills are mentioned less frequently throughout the MBG than other skills, although there is a strong presence of this theme, nonetheless. In the compulsory units, the Science and Engineering Internship promotes the development of technological skills through expecting students to use mathematical and computational thinking, including for the design of simple computational models. Furthermore, the Learning Progressions outline how the socio-cognitive resource of Digital Culture can be integrated into Natural and Experimental Sciences and Technology through providing access to Socio-cognitive virtual laboratories, databases and simulations, and thus further reinforcing that the development of technological skills is an overarching theme.

For the optional units, the General Competences also demonstrate this theme by expecting students to use information and communication technologies to process and interpret information. Moreover, the development of technological skills can be inferred from some of the Extended Disciplinary Competences for Experimental Sciences, as these include using specialised tools and equipment and designing prototypes and models – all of which will likely involve the application of technology.

6. Effective collaboration and communication

Both communication and collaboration are skills mentioned throughout the Mexico curricula. For example, the compulsory units include repeated reference to highlighting the importance of working collectively and the transversal relationships describe that there are different ways for students to communicate their ideas.

For the optional units, while not explicitly present in the Extended Disciplinary Competencies for Experimental Sciences specifically, the General Competences evidence this theme by outlining expectations for students to cultivate interpersonal relationships, express ideas, share opinions, and consider others' perspectives. Moreover, the 'effective' aspect of this DP theme is really highlighted through the expectation that students will apply different communication strategies depending on the audience, the context and the objectives of the communication.

7. Awareness of global and local problems and the environmental, ethical, cultural, and social impact of science

References to the impact of science at global and local levels are less explicit than the other DP learning outcome themes. However, it can be inferred from some of the introductions given for the compulsory units that these aspects will be considered during the course. Indeed, the introduction to both 'Conservation of Energy and its Interaction with Matter' and 'Energy in the Processes of Daily Life units' stipulate that students should establish a broader understanding of how the world works and how humanity takes advantage of this knowledge. Furthermore, Science Workshop I expects students to understand how science and technology influence each other and society, as well as how science and technology can offer alternatives to address specific problems in an individual's environment. Also, the MCCEMS expect the Social Sciences Socio-cognitive Resource to be integrated into Natural and Experimental Sciences and Technology through the consideration of social, economic and cultural perspectives.

For the optional units, there is also presence of this theme in the General and Extended Disciplinary Competences. Indeed, the General Competences describe students being able to recognise and understand biological, economic, political and social implications, including environmental damage, in an interdependent global context, and the Extended Disciplinary Competences expect students to apply scientific and technological advances to improve the conditions of their social environment.

Other Themes in the MBG

There are no other themes within MBG science that are not also present in the DP.

Summary

All DP learning outcome themes are present in the MBG's Learning Progressions, which are shared across all science disciplines. Within the Extended Disciplinary Competences (Experimental Sciences), there is also evidence of all DP learning outcome themes. Some themes are heavily emphasised in the MBG (namely conceptual understanding, critical thinking and problem-solving), whilst others are referenced less regularly (insightful investigations and awareness of the impact of science), but nevertheless still have a strong presence.

4.11.2 Content

This section compares and contrasts the content of the DP and MBG curricula falling within the category of biology. The MBG biology-related units are presented below in diagrams which show the key topics and subtopics included in each.

Figure 24: Visualiser of common science content in the MBG

Core curriculum component	**Natural Sciences, Experimental Sciences and Technology**	1. Matter and its interactions	2. Conservation of energy and its interactions with matter	3. Ecosystems: interactions, energy and dynamics	4. Chemical reactions: conservation of matter in the formation of new substances	5. Energy in the processes of daily life	6. Organisms: structures and processes. Inheritance and biological evolution
Mandatory Extended Core curriculum component	**Natural Science, Experimental Sciences and Technology**	1. Science Workshop I	2. Science Workshop II*				

**At the time of writing this report, the programme of study for Science Workshop II was not publicly available*

Figure 25: MBG biology content visualiser

Optional Extended Core curriculum components	***Selected Topics in Biology I***	**Block I**	Biology as a Science	Explain the purpose of the scientific method to recognize its importance and build critical and reflective thinking.
		Block II	Cellular processes and molecular biology	Relate the cellular structure to the correct functioning of the human body through the identification of biochemical elements that intervene in metabolic processes; to reflexively understand the importance of the study of molecular biology
		Block III	Genetic Engineering and the applications of biotechnology	Question the application of biotechnology and genetic engineering techniques, as well as the consequences of their use in the community, by recognizing the risks and benefits that they present, responsibly promoting the use of products and services derived from it.
	Selected Topics in Biology II	**Block I**	Biodiversity and its study techniques	Recognise the importance of biodiversity and its study techniques to the development of human society, analyzing the biological components that make Mexico a mega-diverse country under a legal framework of species conservation; that allow you to promote in your community, in a responsible manner, actions for the preservation of life.
		Block II	Biology of plants and fungi	Justify the ecological and social relevance of plants and fungi, critically examining their classification based on their anatomical-physiological characteristics, as well as the different uses and applications they have; responsibly promoting the preservation of these species in the community.
		Block III	Animal biology and ethology	Argue the ecological and social relevance of animals, as well as the different functions they have; based on the analysis of their classification according to their structure and physiology, associating this with the biological bases of animal behavior, to responsibly promote the preservation of these species in their community.
		Block IV	Ethnobiology	Define interculturality, valuing different traditions in the community that are related to the use of plants, fungi and animals, encouraging an approach to the cultural roots of the country, promoting the care of species in an environment of respect.

4.11.2.1 Structure

There are many differences in structure between DP biology and the MBG units. Biology in the DP is a distinct, two-year subject, offered at either SL or HL. In contrast, the MBG offers the knowledge area of Natural Sciences, Experimental Sciences, and Technology, which encompasses biology and other sciences. The compulsory units in this knowledge area integrate the sciences and all content within these units is studied to the same level. Only in the optional units of this knowledge area is biology offered as a separate science discipline. The compulsory units altogether span the duration of the MBG, whereas the optional units only span the final year. Therefore, within the MBG, there is more emphasis on breadth of scientific knowledge and less scope to specialise in biology specifically.

DP biology content is broken down into four overarching areas: Unity and diversity, Forms and Function, Interaction and interdependence, and Continuity and change. Each of these has four levels within them: Molecules, Cells, Organisms, and Ecosystems, which are then organised into subtopics. In contrast, the MBG's compulsory units integrate biology (and other science) concepts into six overarching scientific areas such as 'Ecosystems: interactions, energy and dynamics'. For the optional units, the MBG offers Selected Topics in Biology I and Selected Topics in Biology II. These units are each organised into three-four blocks of learning.

4.11.2.2 Content Alignment

The table below represents a simplified summary of the MBG's content alignment with the themes and levels in DP biology (SL and HL). For reasons described above, all compulsory units from the MBG were used and the optional units; Selected Topics from Biology I & Biology II, were also used in biology analysis.

Table 42: Summary of content alignment between the DP biology themes and the MBG

DP biology themes and levels	Presence of SL content in MBG		Presence of AHL content in MBG	
	Compulsory units	Compulsory and optional units	Compulsory units	Compulsory and optional units
A Unity and diversity				
A1 Molecules				
A2 Cells				
A3 Organisms				
A4 Ecosystems				
B Form and function				
B1 Molecules				
B2 Cells				
B3 Organisms				
B4 Ecosystems				
C Interaction and interdependence				
C1 Molecules				
C2 Cells				
C3 Organisms				
C4 Ecosystems			N/A	N/A
D Continuity and change				
D1 Molecules				
D2 Cells				
D3 Organisms				
D4 Ecosystems				
Experimental Programme				

Key:

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

Compulsory units:

- Matter and its interactions
- Conservation of energy and its interactions with matter
- Ecosystems: interactions, energy and dynamics
- Chemical reactions: conservation of matter in the formation of new substances
- Energy in the processes of daily life
- Organisms: structures and processes.
- Science workshop I

Optional units:

- Selected Topics in Biology I & II

Any alignments found in the compulsory units are carried over and combined with those in the optional units, to represent all the biology content offered in the Bachillerato General

As shown in table 42, the MBG has partial alignment with some of the themes and levels in DP biology and shows strong alignment with a few. Each DP theme will be taken in turn and discussed in more detail below.

A. Unity and diversity

Regarding SL content within A: Unity and diversity, of the compulsory units within the MBG, Matter and its interactions shows partial alignment with topic A1.1. The compulsory units of

the MBG also partially align with aspects of cell structure within A2.2 and there is strong alignment between these units and content of A4.1 and A4.2.

The compulsory and optional units of the MBG taken together bring greater alignment between the two curricula, with Selected Topics in Biology II showing partial alignment with DP A1.1 Water. The MBG optional unit Selected Topics in Biology I shows greater alignment with the DP content of A1.2 Nucleic Acids due to the inclusion of content such as the basis of the genetic code, the structure of RNA and DNA and the components of a nucleotide. However, there were areas of content which were not found in the MBG units: hydrogen bonds, cohesion and adhesion of water molecules within topic A1.1, and specific references to complementary base pairing, and conservation of the genetic code as evidence of universal ancestry were not evidenced in the MBG. Many aspects of cell structure are present in Selected Topics in Biology I, and virtually all content within A4.2 Conservation of biodiversity is found in Selected Topics in Biology II.

Regarding AHL content from A. Unity and diversity, there is no alignment between the DP and MBG with regards to A1. Molecules and A2. Cells. However, A3 Organisms shows partial alignment, due to the HL topic of A3.2 Classification and cladistics showing partial presence within the MBG. Within the compulsory units of the MBG there is partial alignment with A4.1 Evolution and speciation due to the presence of adaptive radiation as a source of biodiversity. The MBG's optional unit of Selected Topics in Biology II includes some aspects of classification that are found in topic A3.2, thereby showing partial alignment.

B. Form and function

Regarding SL content, there is no alignment between the MBG's compulsory units and content within B: Form and function. The only alignment with B: Form and function comes from the MBG optional Selected Topics in Biology I unit, which contains some SL content from B2.1 Proteins where there is the inclusion of the structure of cell membranes, as well as simple diffusion across cell membranes. Although the optional units do not include other content from level B2. Cells, the summary table shows that there is a partial presence overall due to B2.1 being a larger topic than the others within theme B. Whilst there is no alignment between the MBG biology and DP for B3. Organisms, it can be noted that this content may be found in the MBG optional subjects of Health Sciences I and II, as they cover the structure of the main systems within the body (musculoskeletal, nervous, cardiovascular and respiratory).

Regarding AHL content, the MBG does not align with any AHL content from theme B. Form and function. There is no mention within the MBG of the more advanced aspects of transport, such as sodium-potassium pumps and gated ion channels in neurons, nor is there mention of adaptations of cells (sperm, egg and cardiac muscle), or specific organelle structure (chloroplasts and mitochondria).

C. Interaction and interdependence

Regarding SL content within C: Interaction and interdependence, topics within C1. Molecules and C4. Ecosystems show partial presence in the compulsory MBG units. The content of C1.2 Enzymes and metabolism can be inferred from the MBG compulsory units 'Organisms, Structures and Functions' and 'Energy in the Processes of Daily Life'. However, this is derived from more all-encompassing statements that describe cellular respiration, the synthesis of new molecules and the breaking of oxygen bonds to form new substances. Overall, C4.

Ecosystems shows partial alignment with the MBG due to the majority of C4.2 content being present within the compulsory unit of 'Ecosystems – Interactions, Energy and Dynamics', alongside little to no presence of content within C4.1.

There is at least partial presence of all theme C levels when viewing the compulsory and optional units of the MBG together. The MBG shows partial presence of topic C1.1 within the optional subject of Biology I, where enzymes and their role in chemical reactions is included. Photosynthesis is less evident in the MBG, therefore much of the SL content of C1.3 shows no alignment. The SL content of C2.2 shows partial alignment with the MBG optional unit Biology I, as it can be inferred that through the study of 'nervous cellular communication' that there would be coverage of at least some aspects of neurons, action potentials and synapses. However, this content *is* found within the MBG optional unit of Health Sciences I. Whilst the SL content of topic C3.1 shows no alignment, there is presence of a small amount of content from C3.2. The MBG optional unit Biology I includes coverage of the innate and adaptive immune system, antigens and antibodies. Within Biology I, it can be inferred that there is also coverage of B lymphocytes and T lymphocytes, however this is not explicitly stated. The MBG optional unit Health Sciences I does contain some SL aspects of C2. Cells and C3. Organisms, such as, hormones, neurotransmitters, synapses, nerve impulses from the former, and pathogens and the primary defence barriers of the latter.

Regarding HL content within theme C. Interaction and interdependence, there is no presence of content within C1. Molecules and C3. Organisms in the MBG, however there is partial alignment with C2.1 and C2.2. There is not enough detail within the MBG curriculum documentation to determine full alignment, but the optional unit Biology I includes the components of and communication within the nervous system, thereby suggesting some coverage of these HL aspects.

D. Continuity and change

Regarding SL content within theme D. Continuity and change, within the MBG compulsory unit 'Organisms, Structures and Processes' there is a very broad reference to homeostasis through references to organisms responding to stimuli and the possibility of breaking states of internal balance. Whilst this may include some aspects of DP topic D3.3 Homeostasis, there is not sufficient evidence to be certain.

There is partial alignment between the MBG optional unit Biology I and DP topic D1.2 Protein synthesis. The process of transcription through the creation of mRNA and tRNA, as well as the effect of mutations on protein structure is all included in the MBG. However, there is no presence of DP topics D1.1 DNA replication or D1.3 Mutations and gene editing, therefore the overall judgement for D1 topics is partial presence in the MBG compulsory and optional units taken together. There is no evidence within the MBG of subject content within D2. Cells or D4. Ecosystems topics.

Regarding the AHL content within D: Continuity and change, there is no alignment found between the DP levels and the MBG. However, within D3.3, all AHL content of this topic (the structure of the kidney and its role in osmoregulation and excretion) can be found within the MBG optional unit of Health Sciences I (Selected Topics).

Additional biology content within the MBG

The MBG optional units contain some biology content which is not covered by DP biology and is summarised in the table below.

Table 43: MBG biology content which is not covered in the DP

Significant MBG biology content which is not included in the DP*
○ GMO products, biotechnology ○ Plants and fungi endemic to Mexico and the importance of their preservation ○ Ethnobiology

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

The optional unit Biology I of the MBG contains Block III: Genetic Engineering and the applications of biotechnology. Within this block, students will study the uses and implications of biotechnology within a social, environmental and economic context. In addition, this block includes the institutions and regulations for GMO product use in Mexico.

Within the 'discipline focus' description of the optional Biology II unit, it states that it will address the study ethnobiology and bring students "closer to the cultural roots of the use…of plants, fungi and animals…promoting a respectful environment of interculturality".[174] This is expanded on in the description of the 'purpose' of Block III which states that students will argue the ecological and social relevance of animals, to responsibly promote the preservation of species.

Experimental programme

The DP's experimental programme is outlined in a way that emphasises the need for students to enhance and embed their understanding through practical work and the development of scientific skills such as experiments, databases, simulations and modelling. However, the realities of this within each school may differ in terms of the exact practical activities carried out and the context these activities are conducted within. The MBG curricula make references throughout the science subject area to activities that may be described as practical experiments. For example, the common Core unit Matter and its Interactions includes a statement where, throughout the course, students will "carry out practices related to the nature of matter and its properties".[175] This goes further to then describe how students will develop skills such as using models and obtaining and analysing data, and the MBG optional unit Selected Topics in Biology I describes students applying steps of scientific methods. These aspects suggest a strong presence of practical work within the MBG.

Summary

In summary, at both SL and HL, the MBG compulsory units show little alignment with the DP in terms of both breadth and depth. The MBG compulsory units show presence of content within themes A. Unity and diversity, and C. Interaction and interdependence, but there is little to no content from themes B. Form and function and D. Continuity and change. The MBG compulsory units do not include any AHL content from any DP themes, showing that the DP biology goes into much greater depth than the MBG compulsory units. Regarding the MBG compulsory and optional units taken together, this shows greater alignment between the MBG

[174] Undersecretary of Upper Secondary Education. (2018). *Selected Topics in Biology II.*
[175] Mexican Secretariat of Public Education. (2023). *Learning Progressions in the area of Natural Sciences, Experimental Sciences and Technology.* p. 36.

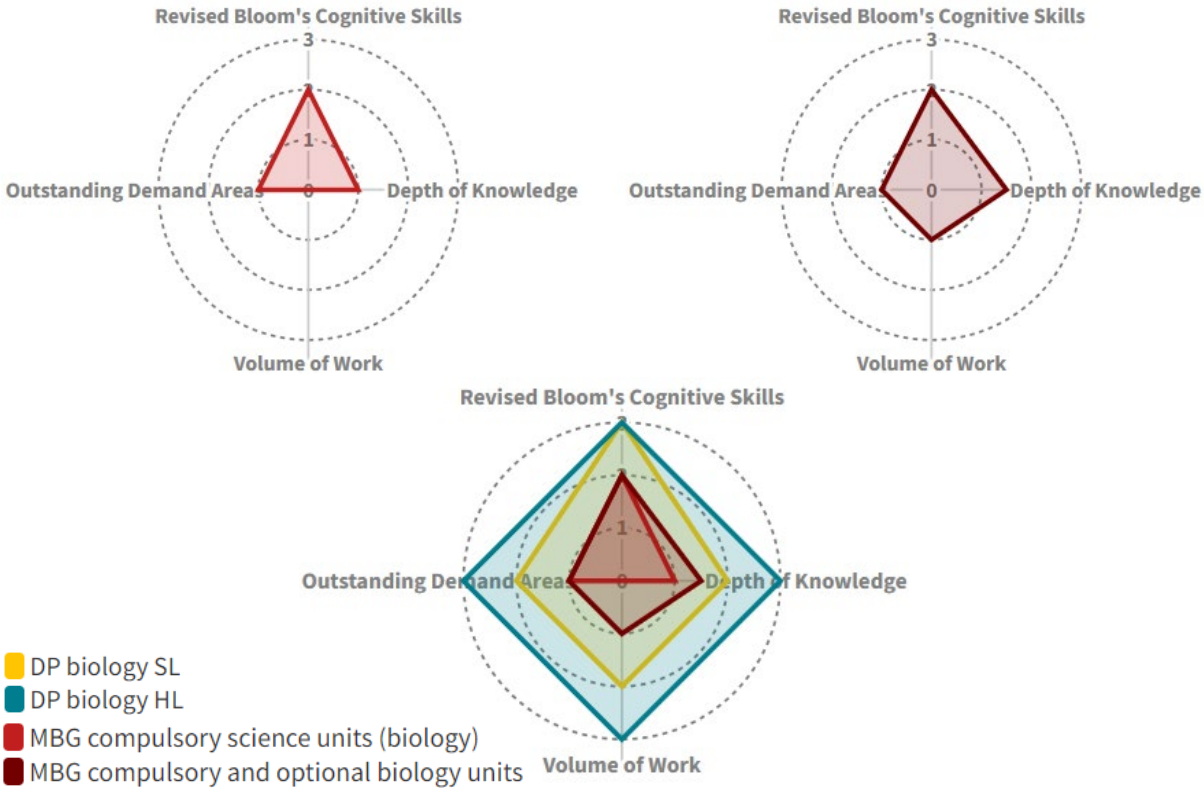
and the DP. At SL, there is some level of alignment with each of the DP biology themes, showing slightly more breadth than the MBG compulsory units alone. At HL, the compulsory and optional units taken together contain little DP AHL content, with only one level from theme A. Unity and diversity, and one level from theme C. Interaction and interdependence showing partial alignment. This demonstrates that the DP biology course has a greater breadth and depth than the MBG.

Some differences in content alignment may be due to the structure of the curriculum and the subjects that are offered by the MBG. For example, the entire content of HL topic A2.3 and both some SL and HL content of theme B are found within the optional Health Sciences units of the MBG, rather than biology. Having said this, the DP still covers a wider range of biology content, to a much greater depth, than the MBG.

4.11.3 Demand

The DP and MBG curricula were analysed using the same demand tool in order to create a demand profile for DP biology SL, DP biology HL, MBG compulsory science units (biology) and the MBG compulsory and optional biology units. These demand profiles are presented below in the form of radar diagrams, with the last diagram showing all profiles superimposed in one place, enabling immediate visual comparison.

Figure 26: Visual representations of subject demand



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 SL and HL received a score of 3 for this category.
  - For the MBG compulsory units and the MBG compulsory and optional units (combined), a score of 2 was given. Whilst there is strong evidence of skills such as analysis, problem-solving and showing innovation, this was not tailored to subject content. A score of 2 was given due to statements being too generalised. Whilst the Extended Disciplinary skills are written with a scientific focus, this did not warrant raising the score above a 2 as there was still not enough evidence of the synthesis and creation of higher order thinking skills.

- Regarding the score for **Depth of Knowledge**:
  - DP biology SL received a score of 2, DP HL received a score of 3 for depth of knowledge.
  - The MBG compulsory science units has been given a score of 1 for depth of knowledge. The course content is fairly top-level and shows evidence of being covered in a fairly shallow way. The MBG compulsory and optional science units has been given a higher score of 1.5. This is due to the presence of higher-level content and more challenging DP content found in the MBG optional units, rather than being present in the Core units.

- Regarding the scores for **Volume of Work**:
  - DP biology SL received a score of 2, DP HL received a score of 3 for volume of work.
  - A score of 0 was given for the MBG compulsory science units. Due to the low score given for depth of knowledge, a large amount of time is devoted to covering content of a basic level. The amount of biology content in the MBG is fairly low and therefore students have a generous amount of time to cover foundational level biology, hence the score of 0. The MBG compulsory and optional science units taken together have been given a score of 1 for volume of work. The addition of the optional selected biology topics in the MBG gives a greater workload and therefore a higher score is justified. However, whilst there were some references to aspects of DP HL biology content, most of the more challenging components were found in the Health Science MBG optional units. Therefore, the amount of time given to the compulsory and optional units together was still considered to be generous and therefore warranted a score of 1.

- Regarding the scores for **Outstanding Areas of Subject Demand**:
  - DP biology SL received a score of 2, DP HL received a score of 3 for outstanding areas of subject demand.
  - The MBG compulsory units alone, and the MBG compulsory and optional units combined, received the same score of 1 for this category. The interdisciplinary nature and significant real-world focus of the MBG units results in a strong emphasis on connections. Moreover, there was evidence of project-based learning, which contains scope for students to explore scientific concepts in-depth. Altogether, these aspects were deemed to warrant a score of 1.

4.12 Japan

The Japanese education system includes six years of elementary school followed by six years of secondary school, which is divided into three years of lower secondary (grades 7-9) and three years of upper secondary (grades 10-12).[176] MEXT – the Ministry of Education, Culture, Sports, Science and Technology – regulates the education system from kindergarten to upper secondary school and develops curriculum standards known as the *National Course of Study*.[177] The *Course of Study* is revised approximately once every 10 years; the most recent revision took place in 2018 and was implemented from 2020 to 2022. [178]

The courses offered in high schools providing upper-secondary education are classified as general, specialised, or integrated. General courses, and their associated subjects, are suitable for those wishing to progress to higher education or employment, but who do not intend to pursue a specific vocational area. In contrast, specialised courses provide vocational or specialist education for those who intend to pursue a particular vocational area or career. There are two types of subjects offered in specialised courses: industry and non-industry. Integrated courses, introduced in 1994, offer a variety of subjects that draw from both general and specialised courses.[179]

A minimum of 74 credits is required to graduate high school[180] and students are required to study compulsory subjects from the following areas:

- Japanese Language
- Geography and History
- Civics
- Mathematics
- Science
- Health and Physical Education
- Arts
- Foreign Language
- Home Economics
- Information
- Comprehensive Inquiry or Inquiry-based Study of Science and Mathematics.

For Science, students are required to choose two subjects from among ‘Science and Human Life’, ‘Basic Physics’, ‘Basic Chemistry’, ‘Basic Biology’ and ‘Basic Earth Science’ (one of which will be ‘Science and Human Life’), **or** three subjects from among ‘Basic Physics’, ‘Basic Chemistry’, ‘Basic Biology’ and ‘Basic Earth Science’.

In addition to compulsory subjects, students study electives in order to reach the minimum credit requirement. Optional subjects are offered in the same areas as listed above. There is

[176] National Information Centre for Academic Recognition Japan (NIC-Japan). (n.d.). *Overview of the Japanese Education System*. Available from: https://www.nicjp.niad.ac.jp/en/japanese-system/about.html
[177] MEXT. (2018). *High School Course of Study. Chapter VI Institutions of Higher Learning.* p. 5-6. Available from: 高等学校学習指導要領（平成30年告示）
[178] MEXT. (2018). *High School Course of Study. Supplementary Provisions (Ministry of Education, Culture, Sports, Science and Technology Decree No. 13 on March 30, 2006).* p. 11.
[179] MEXT. (n.d.). *Principles Guide Japan’s Educational System.* Available from: https://www.mext.go.jp/en/policy/education/overview/index.htm
[180] MEXT. (2018). *High School Course of Study. Chapter VI Institutions of Higher Learning.* p.5-6.

also a wide range of industry and non-industry specialised subjects to choose from. Industry specialised subjects have the following subject areas: Agriculture, Industry, Business, Fisheries, Home Economics, Nursing, Informatics, and Welfare.[181] Non-industry specialised subjects are organised into the areas of: Science and Mathematics, Physical Education, Music, Art and Design, and English. Students studying vocational courses must have a minimum of 25 credits from specialised subjects and schools are to determine the credits for each subject.

The biology subjects from the Japanese High School Curriculum (JHSC) which were used in the analysis are described below.

Advanced Biology[182]
Regarding general subjects, the JHSC offers Basic Biology and Advanced Biology. Advanced Biology carries four credits and is an optional subject that can be studied after Basic Biology. The analysis focused on Advanced Biology, as it aligns more closely with the upper secondary level.

Biology for the Science and Mathematics Course[183]
The JHSC also offers specialised science subjects, with one subject available for each science discipline. Biology for the Science and Mathematics Course (SMC) combines the content from the general subjects – Basic and Advanced Biology – while providing opportunities for further expansion.

4.12.1 Learning Outcomes

This section compares and contrasts the learning outcomes of curricula falling within the category of science. Ecctis extracted learning outcome themes for DP physics, chemistry and biology from the sciences subject group's aims and assessment objectives, hence the themes are the same for all the sciences.

The JHSC defines three overarching objectives for the science subject area, outlining the qualities and abilities students should develop. These concise objectives are further elaborated in the *Commentary on the High School Curriculum Guidelines for Science*. Both the objectives and their explanations were considered in the learning outcome analysis.

The following table displays the presence of the learning outcome themes that were extracted from the DP science learning outcomes and indicates if and where they were judged to have presence within the learning outcomes of the JHSC science subjects.

[181] MEXT. (n.d.). *Principles Guide Japan's Educational System.*
[182] MEXT. (2018). *High School Course of Study. Science.* p. 103-130. Available from: 高等学校学習指導要領（平成30年告示）
[183] MEXT. (2018). *High School Course of Study. Science and Mathematics.* p. 437-441.

Table 44: Presence of the DP sciences subject group learning outcome themes in the JHSC science subjects.

Themes extracted from the learning outcomes of the DP sciences subject group	Presence in the JHSC	
1. Conceptual understanding and making connections.		Partially present in the science objectives.
2. Use and application of knowledge, methods, tools, and techniques that characterise science.		Partially present in the science objectives.
3. Creativity and critical thinking (problem-solving, analysis, evaluation, and synthesis).		Partially present in the further explanations of the science objectives.
4. Apply skills necessary to carry out insightful and ethical investigations (planning, collecting data, organising, following ethical guidelines).		Strongly present in the science objectives. Skills in scientific exploration and investigation are greatly emphasised.
5. Development of technological skills.		Not generally evident in the science objectives, but present in Physics (SMC).
6. Effective collaboration and communication.		Not evident in the science objectives.
7. Awareness of global and local problems and the environmental, ethical, cultural, and social impact of science.		Partially present in the further descriptions of the science objectives.

Key:

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

Presence of the DP's Learning Outcome Themes

The JHSC learning outcomes for science have some degree of alignment with most of the DP learning outcome themes. However, the DP themes tend to only be partially present, and two themes have little to no presence in the JHSC learning outcomes. The extent to which each theme is present in the JHSC learning outcomes is discussed below.

1. Conceptual understanding and making connections

This DP theme is partially present in the JHSC science learning outcomes. The first science objective describes students deepening their understanding of natural objects and phenomena and its further description states that students will understand scientific concepts, principles and laws. However, conceptual understanding, or making connections within the subject or to other subjects is not explicitly required by the objectives.

2. Use and application of knowledge, methods, tools, and techniques that characterise science

This DP theme is also partially present in the JHSC science learning outcomes. The science objectives somewhat demonstrate this theme through expectations that students think scientifically, make observations, and develop skills for conducting scientific exploration and investigation. These aspects may encompass methods, tools and techniques that characterise science, but it is not explicit enough to determine a strong presence of this theme.

3. Creativity and critical thinking (problem-solving, analysis, evaluation, and synthesis)

This DP theme is partially present in the JHSC science learning outcomes. Critical and creative thinking skills are not explicitly evident in the science objectives themselves, however the further explanation of these describe students independently identifying and considering

problems, analysing natural objects and phenomena in terms of qualitative and quantitative relationships, and making judgements based on scientific evidence. However, analysis, evaluation and synthesis generally receive less emphasis compared to the DP science learning outcomes.

4. Apply skills necessary to carry out insightful and ethical investigations

There are many references in the JHSC learning outcomes to investigations and the skills required to conduct them. Indeed, the science objectives describe how students will develop skills related to experiments, the ability to investigate scientifically and an attitude of "proactively engaging with natural objects and phenomena"[184]. The further explanations of the objectives state that students should make predictions or hypotheses and conduct observations and experiments to verify these. They also include that students will conduct experiments on a topic of their choosing and analyse and interpret the results. Hence there is an overall strong presence of this DP theme in the JHSC learning outcomes.

5. Development of technological skills

This DP theme has little to no presence in the JHSC learning outcomes, as the science objectives do not focus on the development of technology skills. Indeed, while students are to find topics for investigation and analyse results, there are no explicit references to the use of technology or how to achieve these objectives. However, the development of technology skills receives more focus in the specialised Physics (SMC) subject, which requires students to deal with analytical techniques using computers.

6. Effective collaboration and communication

Effective collaboration and communication skills are not included in the JHSC learning outcomes. While these skills may be used during scientific inquiry and experiments, there are no specific requirements in JHSC the learning outcomes.

7. Awareness of global and local problems and the environmental, ethical, cultural, and social impact of science

This DP theme has a partial presence in the JHSC science learning outcomes. The explanation of the science objectives highlights aspects of the current global context, including the conservation of the natural environment and the growing role of science and technology. It emphasises that, to build a sustainable society that takes into account global issues, it is important for students to consider multiple perspectives and make evidence-based judgements. However, there is no explicit requirement for students to be aware of global issues, nor is there clear evidence that they need to consider the cultural, ethical and social impacts of science.

Other Themes in the JHSC

There are no significantly different themes or skills within the JHSC science learning outcomes which are not also present in DP science learning outcomes.

Summary

Among the DP science learning outcome themes, only developing skills for scientific investigation is well-evidenced in the JHSC science learning outcomes. Four other themes–conceptual understanding, methods and techniques that characterise science, critical thinking skills, and awareness of local and global problems–are partially present. However, two DP themes–the development of technological skills and the use of communication and

[184] MEXT. (2018). *High School Course of Study. Science*. p 103.

collaboration–have little to no presence in the JHSC science learning outcomes. While these skills may be incorporated into science teaching and learning, they receive less emphasis in the JHSC science outcomes compared to the DP.

4.12.2 Content

This section compares and contrasts the content of the DP and JHSC falling within the category of biology. The content of the JHSC biology subjects is presented below in diagrams which show the key topics and subtopics included in each.

Figure 27: JHSC biology content visualiser.

General Subjects	**Basic Biology**	(1) Characteristics of organisms	(a) Commonality and diversity of living organisms			
			(b) Genes and their functions	A. Genetic information and DNA	B. Genetic information and protein synthesis	
		(2) Regulation of the human body	(a) Regulation by the nervous system and endocrine system	A. Transmission of information	B. Mechanism for maintaining the internal environment	
			(b) Immunity	A. Function of the immune system		
		(3) Biodiversity and ecosystems	(a) Vegetation and succession			
			(b) Ecosystems and conservation	A. Ecosystems and biodiversity	B. Ecosystem balance and conservation	
	Advanced Biology	(1) Evolution of living things	(a) The origin of life and the evolution of cells			
			(b) Mechanisms of genetic change and evolution	A. Genetic changes	B. Mechanism of evolution	
			(c) Phylogeny and evolution of organisms	A. Phylogeny and evolution of organisms	B. Human lineage and evolution	
		(2) Life phenomena and materials	(a) Cells and molecules	A. Biological materials and cells	B. Life phenomena and proteins	
			(b) Metabolism	A. Respiration	B. Photosynthesis	
		(3) Genetics	(a) Expression and development of genetic information	A. Genetic information and its expression	B. Regulation of gene expression	C. Development and gene expression
			(b) Technology that handles genes	A. Genetic technology		
		(4) Organisms' responses to the environment	(a) Organic compounds	A. Hydrocarbons		
			(b) Animal reactions	A. Reception and response to stimuli	B. Animal behaviour	
			(c) Plant responses to the environment	A. Plant responses to the environment		
		(5) Ecology and the environment	(a) Populations and communities	A. Population	B. Biological communities	
			(b) Ecosystem	A. Material production and circulation in ecosystems	B. Ecosystems and human life	

Specialised Subject	**Biology for the Science and Mathematics Course**	(1) Characteristics and evolution of living organisms	Refer to content in Basic Biology (Characteristics of the organism) and Advanced Biology (Evolution of living things). Contents will be expanded as necessary, e.g., phylogenetic classification based on comparison of DNA and proteins between organisms will be considered.
		(2) Life phenomena and materials	Refer to content in Advanced Biology (Life phenomena and matter). Experiments on proteins are to be included to explore the functions and properties of enzymes.
		(3) Expression and development of genetic information	Refer to content in Advanced Biology (Expression and development of genetic information). Contents will be expanded as necessary, e.g., gene recombination technology may be considered. Genetic experiments are to be included.
		(4) Organisms' response to the environment	Refer to content in Basic Biology (Regulation of the human body) and Advanced Biology (Organisms' responses to the environment). Contents will be expanded as necessary, e.g., immunodeficiency and flower bud formation may be considered.
		(5) Ecology environment	Refer to content in Basic Biology (Biodiversity and ecosystems) and Advanced Biology (Ecology and environment). Including field observations or surveys. Contents will be expanded as necessary, e.g., the current situation regarding changes in and conservation of global ecosystems and the consideration of concrete measures to protect them.

Structure

Like DP biology, the JHSC general subjects offer two levels of study, Basic Biology and Advanced Biology. Similar to how AHL content builds upon SL content, the Advanced Biology content builds on that of Basic Biology. However, Basic Biology has significantly lesser breadth and depth than SL. This reflects that Japan's upper secondary begins a year earlier and also requires students to study a wider range of science disciplines. The JHSC specialised subjects do not offer different levels of study for biology. Instead, a single subject, Biology (SMC), is offered, which covers the content from both Basic Biology and Advanced Biology, with opportunities for further expansion.

DP biology content is organised down into four themes: *Unity and Diversity*, *Form and Function*, *Interaction and Interdependence*, and *Continuity and Change*. Each of these themes has four levels of organisation within them: *Molecules*, *Cells, Organisms*, and *Ecosystems*, which are then organised into topics. In contrast, JHSC biology subjects organise content between three and seven topics.

Content Alignment

The following table presents a simplified summary of the content alignment that JHSC biology has with the themes and levels of DP biology (SL and AHL content). The analysis of JHSC Advanced Biology also considers the content that will have been studied in the pre-requisite subject, Basic Biology. Biology (SMC) encompasses the content from Advanced Biology (and Basic Biology) and expands it.

Table 45: Summary of content alignment between the DP biology themes and levels and JHSC biology content.

DP biology themes and levels	Presence of SL content in Advanced Biology/Biology (SMC)	Presence of AHL content in Advanced Biology/Biology (SMC)
A Unity and Diversity		
A1 Molecules		
A2 Cells		
A3 Organisms		
A4 Ecosystems		
B Form and Function		
B1 Molecules		
B2 Cells		
B3 Organisms		
B4 Ecosystems		
C Interaction and Interdependence		
C1 Molecules		
C2 Cells		
C3 Organisms		
C4 Ecosystems		N/A
D Continuity and Change		
D1 Molecules		
D2 Cells		
D3 Organisms		
D4 Ecosystems		
Experimental Programme		

Key:

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

Overall, JHSC biology content has limited alignment with DP biology content. There is some alignment, primarily with the SL content of the themes *C. Interaction and Interdependence* and *A. Unity and Diversity*. However, there is little to no alignment with the DP themes *B. Form and Function* and *D. Continuity and Change*. Indeed, most of the key topics from the levels of these themes, such as *B2.3 Cell specialisation*, *B3.1 Gas exchange*, *B3.2 Transport*, *B4.2 Ecological niches*, *D3.2 Inheritance*, *D4.2 Sustainability and change*, and *D4.3 Climate change* have little to no presence in the content of JHSC biology. In addition, there are also topics from other themes which have little to no presence, such as *A1.1 Water*, *A1.2 Nucleic acids*, *A4.2 Conservation of biodiversity*, and *C3.2 Defence against disease.*

The topics that JHSC biology best aligns with are *C1.2 Cell respiration*, *C4.1 Populations and communities*, and *D1.1 DNA replication*. In addition, the emphasis in the JHSC biology on scientific investigation results in a strong alignment with the DP's experimental programme at SL. Practical work, inquiry, and consideration of problems are all present in JHSC biology, though it can be noted that there is no evidence of a collaborative project. Moreover, it can be noted that a small amount of AHL content is present in JHSC biology. JHSC Advanced Biology covers a topic on the origin of life and the evolution of cells, which somewhat aligns with the HL topic of *A2.1 Origins of cells* and the AHL content of *A2.2 Cell structure*. There is also partial alignment with the AHL content of *C3.1 Integration of body systems* and *D4.1 Natural selection*.

Content can be developed and expanded in the specialised subject, Biology (SMC). However, only a few examples of this extended content are given, such as genetic experiments, phylogenetic classification, immunodeficiency, and field observations. Therefore, Biology (SMC) has the potential to offer greater breadth and depth than Advanced Biology and aligns more closely with DP biology content. However, the extent of this cannot be confirmed and may vary depending on the students taking the subject.

As shown in table 29 below, there is some content covered in JHSC biology which is less present, or not included, in DP biology. This includes some different content covered pertaining to genetic drift, genetic technology, animal behaviour and the nitrogen cycle.

Table 46: JHSC biology content which is not covered in the DP.

Significant JHSC biology content which is not included in the DP*
• Mechanisms of evolution – genetic drift • Genetic technology – restriction enzymes, vectors, and gene amplification techniques • Animal behaviour and the relationship to the functioning of the nervous system • Ecosystems – content on the nitrogen cycle.

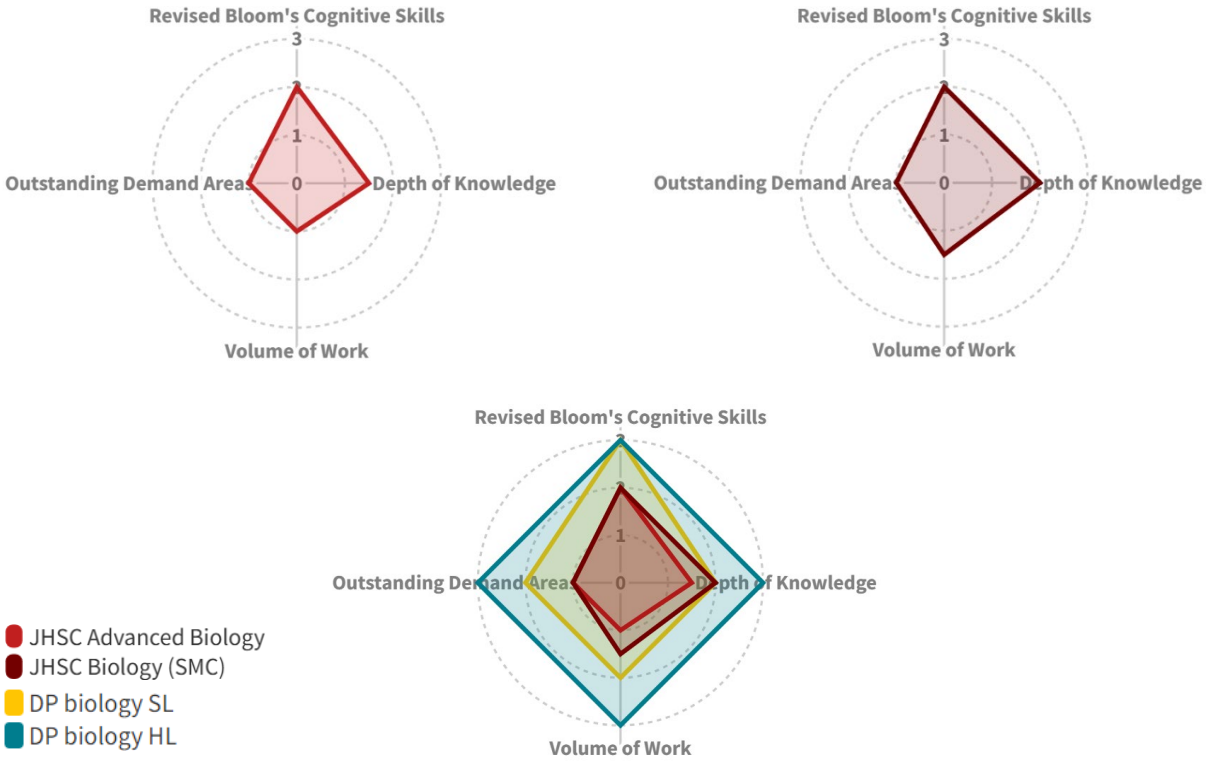
*Some of these areas are present in the DP but the coverage is more limited in comparison to the JHSC.

Overall, the content alignment between DP and JHSC biology is fairly limited. Advanced Biology covers a significantly lesser breadth of content than DP biology SL and HL. The depth of content of Advanced Biology is somewhat less than that of DP SL, however, it can be noted that it may cover some more complex concepts in the occasional area. Biology (SMC) covers the same content as the general subjects while allowing opportunity for expansion. Hence, it may offer greater breadth and depth and align more closely with DP biology content. However, the volume of content and extent of alignment cannot be confirmed and are likely to vary.

4.12.3 Demand

The DP and JHSC biology subjects were analysed using the same demand tool in order to create a demand profile for DP biology SL, DP biology HL, JHSC Advanced Biology, and JHSC Biology (SMC). These demand profiles are presented below in the form of radar diagrams, with the last diagram showing all profiles superimposed in one place, enabling immediate visual comparison.

Figure 28: Visual representations of subject demand.



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 SL and HL received a score of 3.
  - Advanced Biology and Biology (SMC) both received a score of 2. While there was evidence of higher-order thinking skills, particularly in the context of conducting scientific experiments, the emphasis was on analysis, rather than evaluation and synthesis. As a result, a score of 2, rather than 3, was deemed appropriate.

- Regarding the score for **Depth of Knowledge**:
  - DP biology SL received a score of 2 and DP biology HL received a score of 3.
  - Advanced Biology received a score of 1.5. While some of the activities outlined for the subject demonstrated strategic thinking, the depth of the content covered was not sufficient to merit a score of 2. Biology (SMC) received a score of 2, based on the assumption that the content of Advanced Biology would be extended.

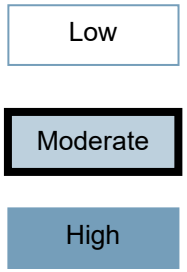
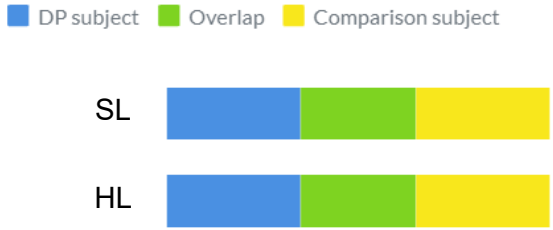
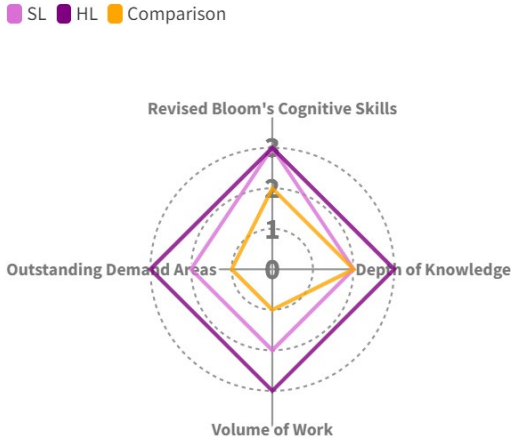
- Regarding the scores for **Volume of Work**:
  - DP biology SL received a score of 2 and DP biology HL received a score of 3.
  - Advanced Biology received a score of 1. The subject covers a breadth of content, but the majority of time is spent on topics of basic depth, resulting in a moderate volume of work. Biology (SMC) received a score of 1.5, based on the assumption that its content would be broader and deeper than Advanced Biology. However, this score is an estimate, as the extent of additional content is not defined, and schools have the flexibility to determine the number of credits for the subject.

- Regarding the scores for **Outstanding Areas of Subject Demand**:
  - DP biology SL received a score of 2 and DP biology HL received a score of 3.
  - Both Advanced Biology and Biology (SMC) received a score of 1, based on the emphasis on project-based learning and scientific inquiry.

5. Key Findings

This section summarises the alignment and main similarities and differences found between the DP and the comparison subjects of each of the eleven comparison programmes in this study.

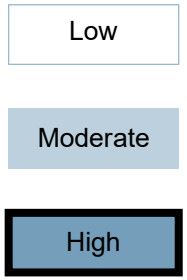
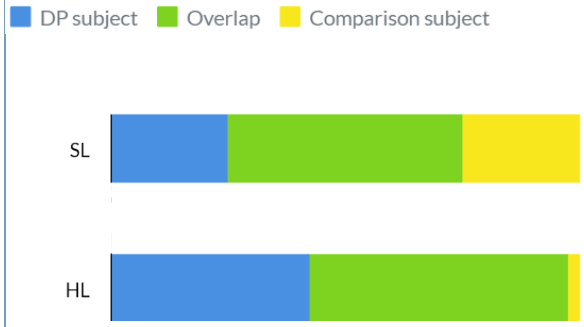
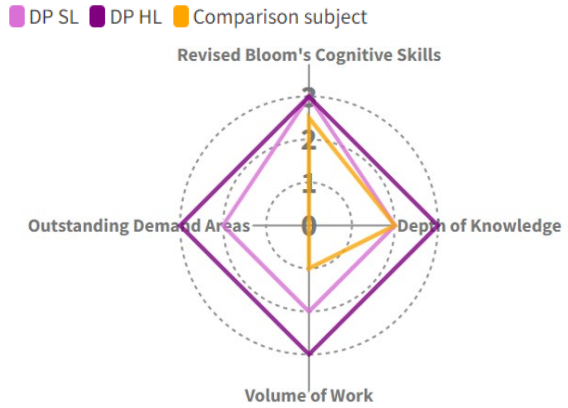
Key:

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.

5.1 Australia (Victoria)

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

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

Subject name	Learning outcomes alignment	Content alignment	Demand alignment
Biology			

- **Learning outcomes alignment**: the level of alignment between the learning outcomes of DP and VCE biology was found to be high, with all themes extracted from the DP sciences learning outcomes being present in the VCE's. Indeed, the learning outcomes of VCE biology similarly focus on developing skills of scientific inquiry, technological skills, application, creative and critical thinking, and awareness of global issues and environmental and societal implications. Furthermore, the updated VCE biology curriculum demonstrated the theme of conceptual understanding more strongly than other VCE science curricula.

- **Content alignment**: there is significant content overlap between VCE and DP biology, for both SL and HL. Compared to SL, VCE biology covers a similar number of topics, as there is significant content overlap between them and both contain similar levels of unique content (i.e. content which is present in one course but not in the other). Compared to HL, while VCE biology does cover some HL topics, the latter features substantially more additional content.

- **Demand alignment**: the VCE biology course was found to be closer to the DP biology SL course in demand level, though the latter scored higher for volume of work and number of stretch areas. The DP HL course was found to score significantly higher than VCE biology, specifically for depth of knowledge, volume of work and stretch areas.

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

- **Similarities in learning outcomes:** all the seven general learning outcome themes extracted from DP biology are found to be strongly present in VCE biology. There is a high degree of alignment regarding the emphasis given to themes – VCE similarly emphasises application of skills and knowledge, scientific inquiry, creative and critical thinking, development of technological skills, awareness of global issues and environmental and societal implications, and communication and collaboration skills. The VCE biology curriculum was also recently updated and now demonstrates a stronger focus on conceptual understanding and making connections – a key element of the DP sciences group.

- **Similarities in content:** VCE biology covers a fair proportion of the DP SL topic areas in biology, especially within A. Unity and diversity, such as nucleic acids, conservation of biodiversity, and evolution and speciation. There is also a strong presence of D. Continuity and change SL content in relation to DNA replication, protein synthesis, cell and nuclear division, water potential, inheritance, homeostasis, and natural selection. In addition, VCE biology also covers some AHL content involving proteins, organelles and compartmentalization, enzymes and metabolism, DNA replication, protein synthesis, nuclear cell and division, and inheritance. Therefore, VCE biology covers some specific areas in similar detail to DP HL.

- **Similarities in demand:** from a demand perspective, the VCE biology curriculum is closer to the DP biology SL course than the DP biology HL course, with the demand

level of the HL being higher. In particular, the VCE biology's scores for the Bloom's cognitive skills and depth of knowledge demand categories broadly align with DP SL.

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

- **Differences in learning outcomes:** the only difference of note is that VCE biology includes statements about the types of attitudes and values it expects students to develop during their studies of biology, which are reflected in the IB learner profile rather than the DP's specific aims for the sciences subject group.

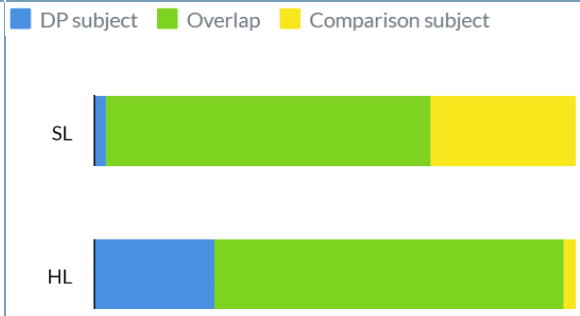
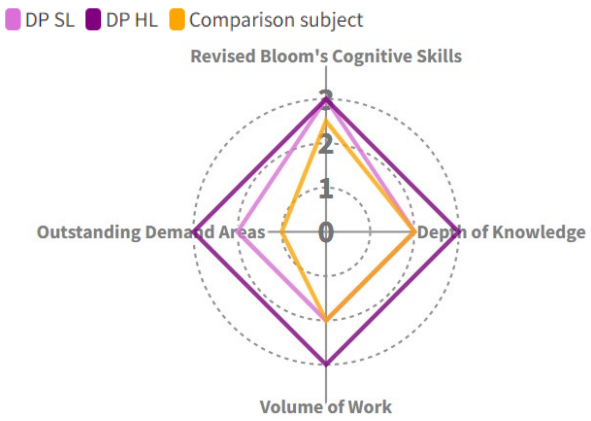
- **Differences in content:** though VCE biology covers both some SL and HL content, there are several topics which are not covered. For SL these include carbohydrates and lipids, transport, ecological niches, neural signalling, transfers of energy and matter, sustainability and change, and climate change. Instead of some SL topic areas, VCE biology includes content which is HL in DP biology. However, a considerable proportion of AHL content is not present or covered in lesser detail, including origins of cells, cell specialisation, chemical signalling, neural signalling, integration of body systems, and all B3. Organisms content. Hence, VCE biology has less breadth and depth than DP HL. There are also structural dissimilarities, as where AHL content in the DP HL typically builds on SL content, in the VCE there is less progression in terms of content between units, with no prerequisite content from Unit 1 being required to take Units 2 and 3.

- **Differences in demand:** from a demand perspective, VCE biology is closer to the DP SL than DP HL, with the demand level of the HL being significantly higher. This is mainly due to the volume of work and outstanding demand areas scores – the DP biology HL has a higher workload and number of stretch areas when compared to VCE biology, for which no stretch areas are identified.

5.2 Canada (Ontario)

The subject level alignment between the DP biology and OSSD biology is represented below: [185]

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

Subject name	Learning outcomes alignment	Content alignment	Demand alignment
Biology	Low Moderate High		

[185] For the purposes of simplicity, the summary visual includes the results from the comparison between the DP (SL and HL) and OSSD biology grades 11 and 12 combined. For specific information on the grade 11 course, refer back to section 5.

- **Learning outcomes alignment**: the level of alignment between the learning outcomes of DP and OSSD biology is high, with all themes extracted from the DP learning outcomes being present in the OSSD's learning outcomes. While there are some small differences in focus – for example, the OSSD emphasising knowledge of Canadian contributions to science and making less explicit reference to scientific communication than the DP – the level of overlap is, nevertheless, substantial.

- **Content alignment**: there is a large amount of content overlap between DP and OSSD biology, for both SL and HL. DP SL has a small amount of content unique to itself, though the majority is shared with the OSSD. DP HL biology has a more significant amount of additional content, though again a considerable proportion is found in the OSSD. Generally, OSSD biology does not contain content which is not present in the DP syllabus.

- **Demand alignment**: OSSD biology has stronger alignment with the DP biology SL course, although it features fewer stretch areas than the latter. The DP HL significantly surpasses OSSD in demand level, featuring more stretch areas, greater depth of knowledge, and a higher volume of work.

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

- **Similarities in learning outcomes:** all seven learning outcome themes extracted from DP biology are present to some extent in all Ontario biology courses. In terms of emphasis on the themes, the OSSD is especially similar in its focus on developing technology skills, developing understanding and making connections, awareness of issues and the impact of science on the environment and society, creativity and critical thinking, and skills of scientific inquiry.

- **Similarities in content:** OSSD biology covers nearly all SL content in the DP biology levels, and often with a similar degree of detail. There is also AHL content covered in similar detail in the topics of nucleic acids, origins of cells, viruses, organelles and compartmentalization, cell respiration, and photosynthesis – plus other AHL topics which are covered in lesser detail. Therefore, there is some considerable alignment with DP HL biology content.

- **Similarities in demand:** the demand of OSSD courses varies significantly by grade (see key difference section below). Taken as a whole, the OSSD biology curriculum is closer to the DP biology SL course than the DP biology HL course, with the demand level of the HL being significantly higher. In particular, the OSSD grade 12 biology's scores for Bloom's, depth of knowledge, and volume of work demand categories mostly align with DP biology SL.

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

- **Differences in learning outcomes:** whilst Ontario similarly sets general outcomes for all sciences through its key science skills and goals, the curricula also have specific 'overall expectations' for each individual course between grade 9 and 12. When these

are used to add context to the goals, it consistently emerges that courses tend to have some learning outcome themes which are not present in the DP, including a focus on Canadians' contributions to science, the recognition of indigenous peoples' knowledge and customs, and an explicit expectation that students understand the careers that study of science can relate/lead to. Furthermore, it can be noted that the emphasis on each theme varies per grade – OSSD science grades 9 and 10 have a more substantial focus on knowledge and understanding, while grades 11 and 12 biology observe a similar level of emphasis on higher order thinking skills as the DP biology course.

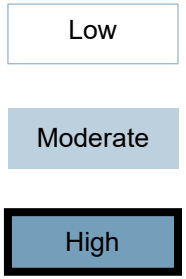
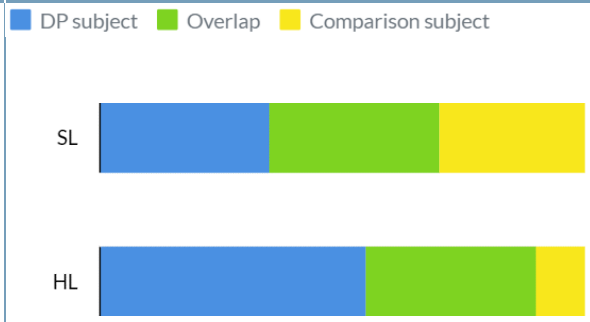
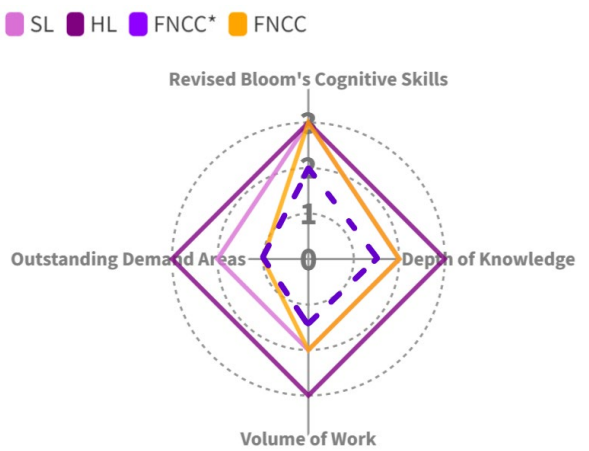
- **Differences in content:** as with other science courses, one of the key differences between the OSSD and DP in relation to biology is that the OSSD programme includes two years of de-streamed general science before specialising in the third and fourth years. As a result, the grades 9-10 science curricula in Ontario have little in common with DP biology in terms of subject content, as only 25% of those courses are dedicated to biology. Taken as a whole, while there is a considerable amount of alignment between DP biology HL and the OSSD biology curriculum, there are several AHL topics included within the DP curriculum which exceed the OSSD in depth and complexity. These include proteins, membranes and membrane transport, cell specialisation, muscle and motility, enzymes and metabolism, chemical signalling, neural signalling, reproduction, homeostasis, natural selection, sustainability and change, and climate change. Overall, OSSD biology exceeds SL in depth of content, but does not contain enough AHL content (or other advanced material) to make it truly comparable to the depth of DP HL biology.

- **Differences in demand:** the demand of OSSD courses varies significantly by grade, with science grades 9 and 10 observing, expectedly, low scores for demand across all categories, and grades 11 and 12 biology observing more similar scores to those of the DP biology SL and HL courses. Taken as a whole, the OSSD biology curriculum is more closely aligned with the DP biology SL course than the HL course, with the demand level of the HL being higher. As with the other sciences, this is mainly due to the outstanding demand areas score – the DP biology HL has a significantly higher number of stretch areas when compared to the OSSD courses.

5.3 Finland

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

Figure 31: Visual representations of subject-level alignment (biology)

Subject name	Learning outcomes alignment	Content alignment	Demand alignment
Biology			

NB: For demand, the FNCC* refers to compulsory modules only, while FNCC represents the full FNCC biology curriculum, including both compulsory modules and the additional optional modules combined.

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

- **Content alignment**: there is a reasonable amount of content overlap between DP and FNCC biology, with the latter comprising of mostly SL topics and some HL topics. However, the FNCC describes the content coverage of these topics in far less detail than the DP, resulting in mostly 'partial' rather than 'full' sub-topic alignments. This is also true for alignment with the DP's experimental programme, with the FNCC only including limited detail on practical experiments and scientific inquiry. Furthermore, despite some overlap in several topic areas, a significant amount of both SL and HL content is absent from the FNCC, especially levels from B. Form and function. The fact that only some SL and HL content is clearly included in the FNCC subjects results in relatively limited content alignment between the DP and FNCC. Overall, the FNCC's volume of content is exceeded by DP HL, which has greater breadth and depth than the former. However, FNCC biology content appears to be of a similar size to DP SL, provided that both compulsory and optional modules are studied.

- **Demand alignment**: the demand of FNCC biology varies depending on how many modules within this subject are taken. When considering only the compulsory modules, the demand of FNCC biology is surpassed by SL to a relatively small degree, and by HL to a larger degree. When taking into account all modules (both compulsory and national optional modules), FNCC biology scores comparably to DP SL, scoring the same in all categories except outstanding areas, in which it received a slightly lower score.

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

- **Similarities in learning outcomes:** FNCC biology covers all learning outcome themes extracted from the DP, though some are more emphasised than others. Many are found within the 'task of the subject' and the 'transversal competences' sections of the curriculum. The FNCC biology places particular importance on the awareness of local and global problems, and creativity and critical thinking.

- **Similarities in content:** for SL, the FNCC shows strong alignment with most levels of theme A. Unity and diversity, and partial alignment with all levels within themes C. Interaction and interdependence and D. Continuity and change. There is also partial alignment between the FNCC and some of the AHL content in the DP biology levels, though the FNCC does not cover these in comparable depth.

- **Similarities in demand:** when all modules (both compulsory and optional) of the FNCC biology syllabus are considered, there is reasonable alignment with the demand of the DP SL. Indeed, the FNCC received the same score as the DP SL in three categories: Bloom's, depth of knowledge and volume of work.

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

- **Differences in learning outcomes:** the themes of applying necessary skills to carry out investigations and demonstrating knowledge that categorises science are not emphasised within the FNCC learning outcomes as extensively as in the DP. Instead, the FNCC learning outcomes are more centred around students developing skills that help them appreciate the impact of their everyday choices and take responsibility for their own actions – e.g. students' understanding the importance of biodiversity and taking an active approach to making sustainable choices.

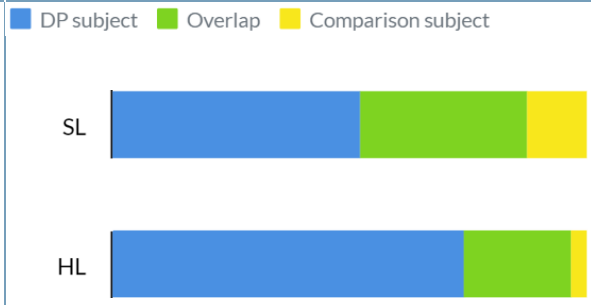
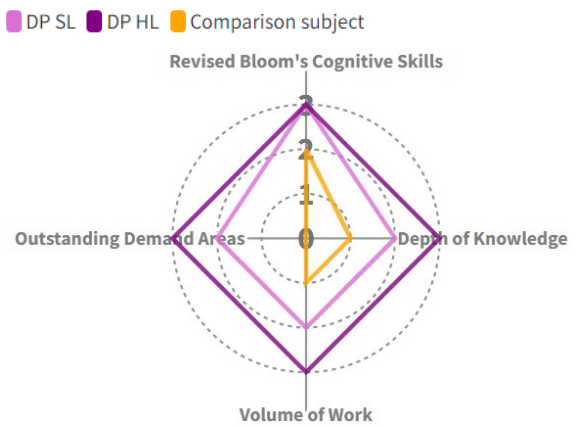
- **Differences in content:** for SL and AHL content, most of theme B. Form and function was not found to overlap with the FNCC biology curriculum. Regarding AHL content, roughly half of the levels within each theme are absent from the FNCC, and those that are included are not covered in comparable depth. Thus, based on the information available in FNCC documentation, the FNCC does not go into the same level of depth as the DP (though it is possible that schools may go beyond what is presented there).

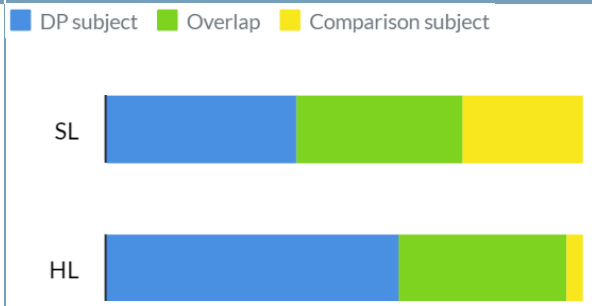
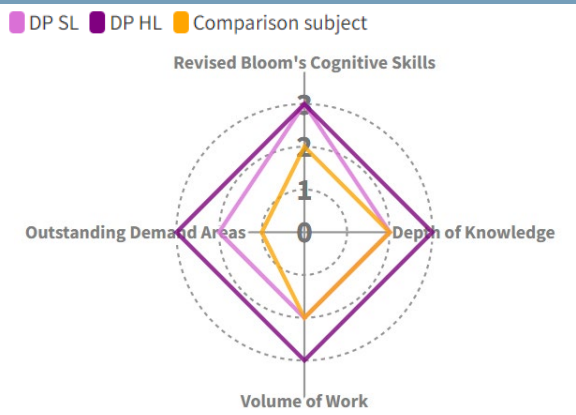
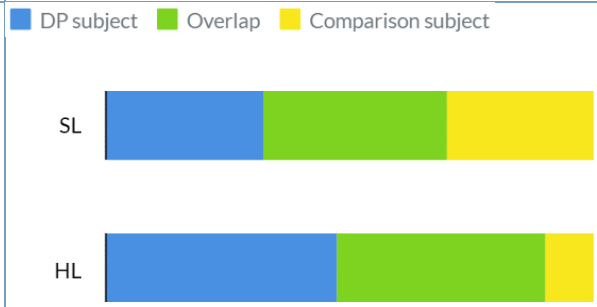
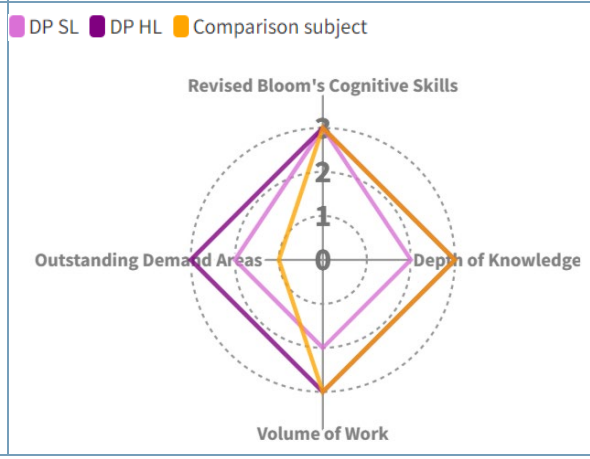
- **Differences in demand:** the FNCC compulsory biology course scored lower than the DP SL and HL course content in all areas. As to the FNCC compulsory and optional biology combined, the scores were similar to those of the DP SL, apart from outstanding areas of subject demand, for which the FNCC scored lower. Regarding the DP HL, the FNCC scored lower than the former for volume of work, outstanding areas of subject demand and depth of knowledge.

5.4 Singapore

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

Figure 32: Visual representations of subject-level alignment (biology)

Subject name	Learning outcomes alignment	Content alignment	Demand alignment
H1 Biology	Low Moderate High		

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 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 theme D. Continuity and change is consistently present across all SGA biology subjects, as is SL content from A2. Cells, B1. Molecules, B2. Cells and C1. Molecules. AHL content is present in H2 and H3 biology, particularly in the themes B. Form and function, C. Interaction and interdependence 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.

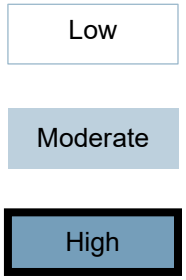
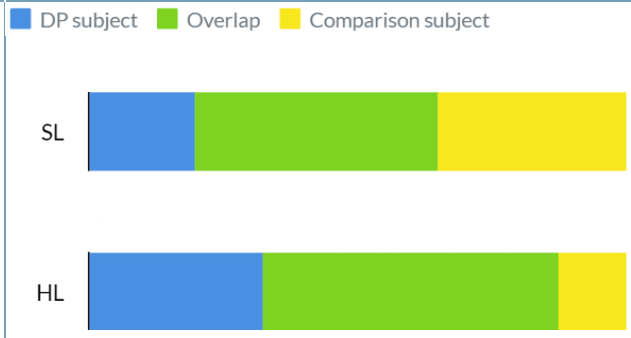
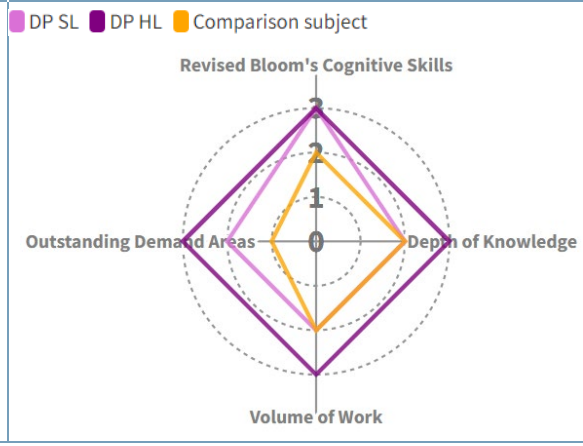
- **Differences in content:** there are many areas of the DP SL and AHL content that are not found in the SGA H1 biology course. A significant portion of SL content from themes A. Unity and diversity and C. Interaction and interdependence is absent, and no alignment with AHL content is present, aside from two levels (D2. Cells and D4. Ecosystems). H2 also does not include a significant amount of SL and AHL content, especially from A. Unity and diversity. Though H3 has more level-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.

5.5 South Korea

The subject level alignment between the DP biology and KHSCG biology is represented below:[186]

Figure 33: Visual representations of subject-level alignment (biology)

Subject name	Learning outcomes alignment	Content alignment	Demand alignment
KHSCG Biology			

[186] The summary visual shows the results from the comparison between the DP (SL and HL) and KHSCG Biology I and Biology II combined.

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

- **Content alignment**: there is a considerable amount of overlapping content between DP and KHSCG biology. SL content from nearly all the biology levels is present in the KHSCG, with most being highly, rather than 'partially', aligned. Furthermore, AHL content from most levels are in KHSCG, though the degree of alignment tends to be partial due to the topics being explored in less detail in the KHSCG. Moreover, features of the DP's experimental programme can also be identified in KHSCG biology. Overall, KHSCG biology has a similar topic coverage to that of the DP and includes more content than what is included at SL, though it does not match the depth of HL.

- **Demand alignment**: the demand level of KHSCG biology is more closely aligned with that of DP SL, with the former scoring the same for depth of knowledge and volume of work, though slightly less for Bloom's cognitive skills and outstanding areas of demand. The level of alignment of the KHSCG with DP HL is lower, as DP HL biology scores higher in all demand categories.

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

- **Similarities in learning outcomes:** there is a high level of alignment between the learning outcomes of DP biology and those of KHSCG biology, with all themes extracted from the DP being strongly evidenced in the KHSCG. The KHSCG curriculum similarly aims to create well-rounded, curious students who have an appreciation for science and its place in the world. Specifically, the KHSCG also aims to develop conceptual understanding, application, skills for scientific inquiry, technological skills, communication and collaboration, creativity and critical thinking, and awareness of global and local problems and the impact of science.

- **Similarities in content:** KHSCG has a large amount of overlapping content with DP biology, at both SL and HL. KHSCG shows high alignment with the majority of levels in DP SL, whereas the coverage of AHL content is mostly partial. Within the AHL content, the KHSCG content is particularly well aligned with the B1. Molecules and C1. Molecules. Generally, there is a high level of similarity between the topic coverage of the DP and that of the KHSCG, as almost all DP levels are present in the KHSCG to some extent.

- **Similarities in demand:** KHSCG scores the same for demand as DP SL for depth and knowledge and volume of work and is generally more aligned with SL than HL for demand.

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

- **Differences in learning outcomes:** no significant differences in learning outcomes were found.

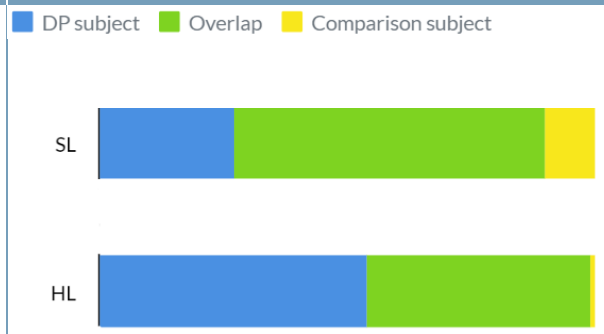
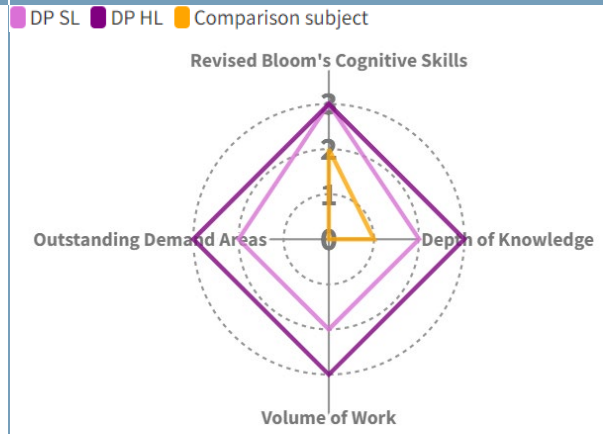
- **Differences in content:** when compared to DP SL, the KHSCG does not cover some aspects of B3. Organisms and B4. Ecosystems and there is only partial alignment with most D. Continuity and change levels. The majority of DP AHL content is covered in the KHSCG, with the exception of levels A1. Molecules and C3. Organisms. The topic coverage of the KHSCG is, thus, well aligned with that of the DP, but the depth of the content covered differs, with AHL content from many of the levels being partially covered. Furthermore, KHSCG contains some content that cannot be found in DP biology, such as the ecological, ethical, legal and social issues associated with the use of biotechnology. The KHSCG also contains a large focus on how science can be used in everyday life with regard to food, make-up, architecture and sports; an aspect that is absent from the DP.

- **Differences in demand:** KHSCG biology scores lower than DP HL for all demand categories and scores less than DP SL for Bloom's cognitive skills and outstanding demand areas.

5.6 United States (NGSS)

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

Figure 34: Visual representations of subject-level alignment (biology subjects)

Subject name	Learning outcomes alignment	Content alignment	Demand alignment
NGSS Life Sciences (biology)	Low Moderate **High**		

- **Learning outcomes alignment**: the level of alignment between the learning outcomes of the DP biology course and those of the NGSS life sciences is high, with most themes extracted from the DP learning outcomes being present in the NGSS's learning outcomes. Indeed, the NGSS also demonstrate a focus on scientific inquiry, critical thinking skills, and communication. However, there are slight differences with regards to the emphasis of certain themes, with the NGSS having a lesser focus on scientific implications and conceptual understanding and a greater focus on use of models and computational thinking.

- **Content alignment**: while there is considerable overlap between the NGSS and DP biology SL, there is limited alignment between the NGSS and the AHL content covered in HL. As to content depth and level of detail covered, this is considerably higher in DP SL and HL than in the NGSS.

- **Demand alignment**: both the DP biology SL and HL considerably surpass the NGSS in demand level. The NGSS score lower in all categories, especially for outstanding areas of demand and volume of work. The NGSS do, however, score more closely to the DP for cognitive skills, as there is evidence of some higher-order thinking such as analysis.

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

- **Similarities in learning outcomes:** the majority of learning outcome themes extracted from DP biology are present to some extent in the NGSS, with similar coverage of acquisition and application of knowledge of ideas, theories and concepts in biology, creative and critical thinking skills, investigation skills, use of technology, and effective communication and collaboration.

- **Similarities in content:** there is considerable alignment of topics between the DP biology SL and NGSS, despite the latter covering content in considerably lower detail and depth. SL topics covered by the NGSS include natural selection, transfers of energy and matter, populations and communities, water, and nucleic acids. Some DP AHL content is also covered by the NGSS, though not in as much depth. These include: nucleic acid, the origin of cells, natural selection, DNA replication, protein synthesis, sustainability and change, and climate change. Moreover, both the NGSS and the DP have somewhat flexible structures, in that neither specifies an order for topics to be studied in, and both allow for practical demonstrations, modelling, and links to real world scenarios.

- **Similarities in demand**: both the DP and the NGSS show some evidence of higher-order thinking skills in their learning outcomes. However, while conceptual thought and critical thinking are predominant in the majority of the DP's course aims, reference to higher order thinking skills in the NGSS is limited.

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

- **Differences in learning outcomes:** there are some evident differences in the extent of the coverage of the DP themes in comparison with the NGSS life sciences. Development of conceptual understanding is not referenced in the NGSS and consideration of ethical, social, environmental, and cultural implications of science is only present in a limited number of performance expectations. Additionally, a couple of outcome themes also emerged as receiving greater emphasis in the NGSS when compared to the DP, namely the larger focus on the ability to use computational thinking and on understanding and applying scientific models.

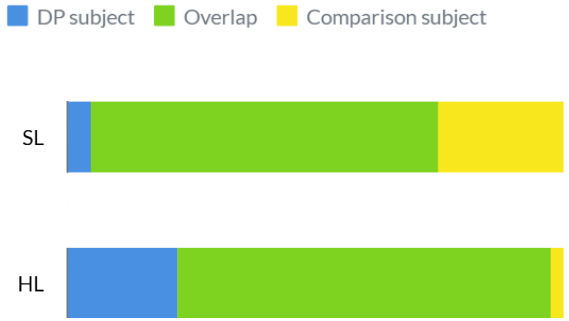
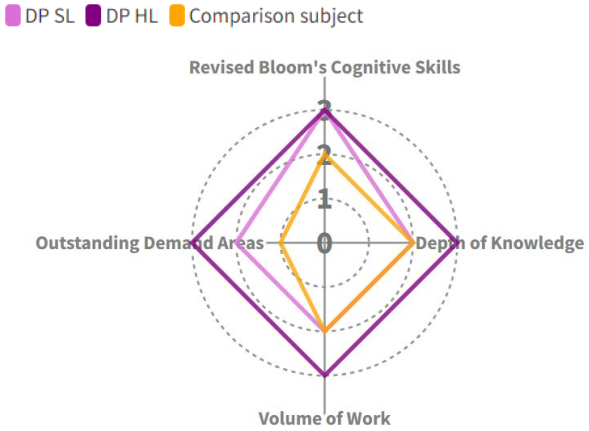
- **Differences in content:** generally speaking, the breadth of content in the NGSS life sciences is significantly lower than that of both the DP biology SL and HL. While there is substantial overlap between the NGSS and the DP biology SL, coverage often lacks sufficient depth and detail to be comparable. Moreover, various DP biology SL topics are altogether absent from the NGSS, including: membranes and membrane transport, organelles and compartmentalisation, transport, enzymes and metabolism, defence against disease, water potential and reproduction. AHL content is mostly absent from the NGSS, and, where present, is not covered in comparable depth.

- **Differences in demand:** from a demand perspective, it is hard to gauge the real demand of the NGSS in practice, as each state is free to independently decide how to implement them. Working purely from the NGSS documentation, the latter have been judged to be of much lower demand than both the DP biology SL and HL courses across all demand categories considered (Bloom's cognitive skills, depth of knowledge, volume of work and outstanding demand areas).

5.7 France

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

Figure 35: Visual representations of subject-level alignment (biology)

Subject name	Learning outcomes alignment	Content alignment	Demand alignment
FB Life and Earth Sciences (LES)	Low Moderate **High**		

*The yellow bar for FB Life and Earth Sciences represents biology-only additional content, it does not represent earth science topics.

- **Learning outcomes alignment**: the level of alignment between the learning outcomes of the DP and FB life and earth sciences is high, with all themes extracted from the DP learning outcomes being present to some extent in the FB's skills. While there are some small differences in emphasis – e.g. the FB exploring the theme of communication and collaboration more extensively than the DP – the level of overlap is, nevertheless, substantial.

- **Content alignment**: there is a large amount of overlap between DP and FB life and earth sciences. There is substantial alignment between DP SL and FB life and earth sciences, though alignment with AHL content is only partial for almost all levels. DP SL covers a small number of topics which are not covered by FB, though the majority of content is shared with FB. With the exception of Earth Science topics, the FB life and earth sciences does not contain content which is not also present in the DP biology syllabus.

- **Demand alignment**: the FB and DP SL share the same scores in the categories of depth of knowledge and volume of work, though the FB falls short of SL scores in the remaining categories. DP HL surpasses FB in terms of demand in all categories.

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

- **Similarities in learning outcomes:** all seven learning outcome themes extracted from the DP biology are present to some extent in FB life and earth sciences. In terms of emphasis on the themes, the FB is especially similar in its focus on conceptual understanding, the use of techniques that categorise science and the awareness of the impact of science. The FB also features clear references to problem-solving and the development of technology skills.

- **Similarities in content:** the FB has some level of alignment with SL content from all DP biology levels, with 13 of these showing strong alignment and only 3 showing partial alignment. With regards to AHL content, there is particularly strong alignment between the FB and the DP D4. Ecosystems, while FB also demonstrates partial alignment with AHL content in ten other levels. The FB life and earth sciences' practical skills also partially aligns with the DP's experimental programme.

- **Similarities in demand:** the demand of the FB life and earth sciences curriculum is more similar to that of the DP biology at SL than at HL. The depth of knowledge and volume of work for the DP SL and FB life and earth sciences both received scores of 2.

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

- **Differences in learning outcomes:** some of the skills within the DP are given slightly different emphasis in the FB earth and life sciences course. For example, the DP theme of communication and collaboration is demonstrated well in the FB, but the latter features greater emphasis on the need for students to 'convince' others than the former. This particular mention of students learning to change someone else's thinking

through good oral presentation and argumentation is more specific in the FB than the DP. Some aspects of the DP's theme focused on awareness of the impact of science are also less apparent in the FB than others. For example, the ethical, cultural and social implications of actions are less evidenced in the FB curriculum than in the DP's.

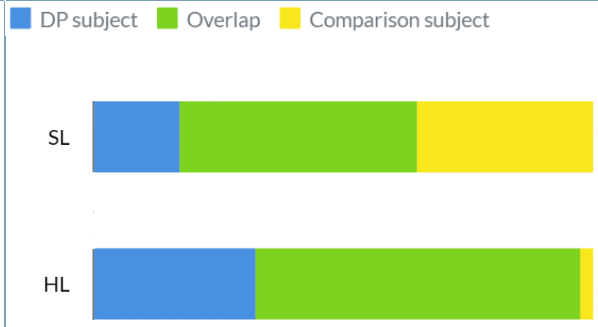
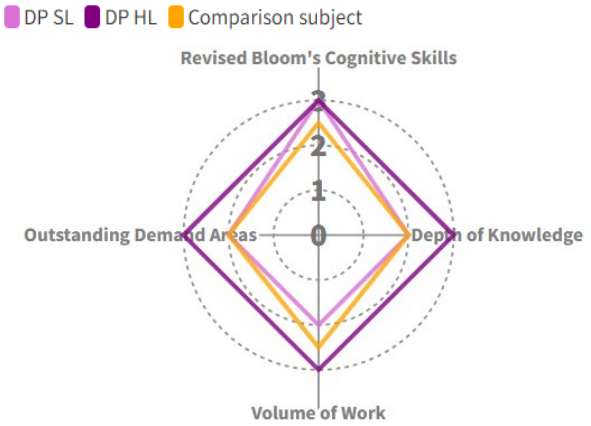
- **Differences in content:** despite there being a great deal of content similarity and overlap between the DP and the FB life and earth sciences, there are some subtle differences between the two. SL content from three DP levels (B2. Organisms, B4. Ecosystems and D2. Cells) is covered in less depth in the FB – e.g. xylem vessels and medical applications of isotonic solutions are present in the DP but not found in the FB. There are greater differences between the DP HL and FB life and earth sciences, with the FB only demonstrating partial alignment with the AHL content of most levels. AHL content in three DP levels (A3. Organisms, A4. Ecosystems and B2. Cells) has little to no presence in the FB course. Due to the combined nature of the FB course, there is Earth Science content covered which is not present in the DP. However, regarding biology content, there are no significant content areas in the FB that are not also found in the DP.

- **Differences in demand:** FB life and earth sciences scored lower than the DP SL and HL in all areas, with the exception of those listed in 'similarities' above. The DP, at both SL and HL, exceeds the FB life and earth sciences when it comes to Bloom's cognitive skills and outstanding demand areas. The DP HL further exceeds the FB in the depth of knowledge and volume of work categories.

5.8 Spain

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

Figure 36: Visual representations of subject-level alignment (biology)

Subject name	Learning outcomes alignment	Content alignment	Demand alignment
SB Biology	Low Moderate **High**		

- **Learning outcomes alignment**: all DP learning outcome themes were present in the SB specific competences (SCs) to some extent. Some themes, such as conceptual understanding, use of techniques that characterise science and creativity and critical thinking, were found to be strongly evident throughout the SCs. Others, such as technological skills. were inferred from the SCs and further descriptions, but not necessarily explicitly stated.

- **Content alignment**: there is a large amount of overlap between the SB and DP biology at both SL and HL. There is less alignment between the DP and the first-year SB biology, geology and environmental sciences, partially due to the combined nature of the SB subject. All DP levels are present to some extent in the second-year SB biology subject; however, for many content areas, particularly those found in the DP at HL, the SB has only partial alignment with the DP.

- **Demand alignment**: taken as a whole, SB biology aligns well with DP biology SL, as it scores similarly in all demand categories. DP biology HL exceeds SB biology in all demand categories.

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

- **Similarities in learning outcomes:** all DP learning outcome themes are present in the SB SCs. The theme of conceptual understanding and making connections is highlighted throughout the SCs, as is the use of techniques that characterise science. The skill requiring creativity and critical thinking is also clearly evident throughout the SCs in references to evaluation and critically analysing research. Collaboration and communication skills are also highlighted as important within the SB; however, there is a greater emphasis on communicating; particularly the ability to debate and present an idea or project.

- **Similarities in content:** in the combined first-year SB biology, geology and environmental sciences subject, greater alignment is seen with DP SL than HL, with SL content from four levels and AHL content from one level showing strong alignment. The second-year SB biology subject features a substantial overlap with DP biology content, particularly at SL. All content areas are present, with nine levels showing strong alignment at SL and three showing strong alignment at HL.

- **Similarities in demand:** as a whole, SB biology aligns strongly with DP SL, scoring the same for depth of knowledge and outstanding demand areas, and similarly for Bloom's cognitive skills and volume of work.

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

- **Differences in learning outcomes:** whilst the SB contains all DP learning outcome themes, some are less emphasised than others. For example, the development of technological skills is not explicitly stated in its own right, though can be inferred from the wording of the SCs. For a student to use 'digital content' a level of competence in the use of technology is required. The analysis and evaluation of experimental data

also likely required the use of technology. The social, ethical and cultural impact of science within the DP theme of awareness of global and local problems is less apparent in the SB. Whilst there is mention of students understanding the constant evolution of science and how the political and social contexts may affect it, there is no explicit reference to the recognition of the social, ethical and cultural impact of science. Within the SB, there is a specific reference to students being able to highlight women's role in scientific research and discoveries. Whilst this is not necessarily missing from the DP, it is not expressed as overtly as it is in the SB.

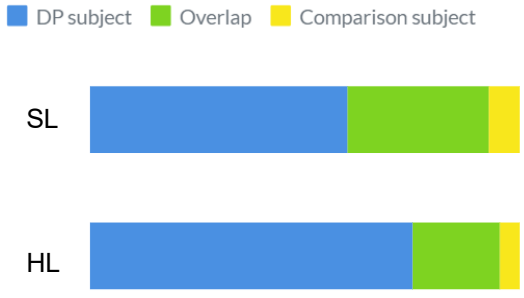
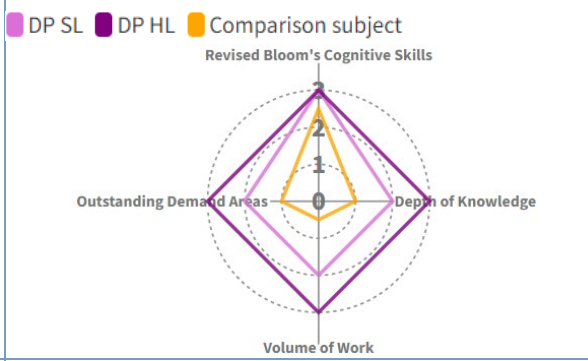
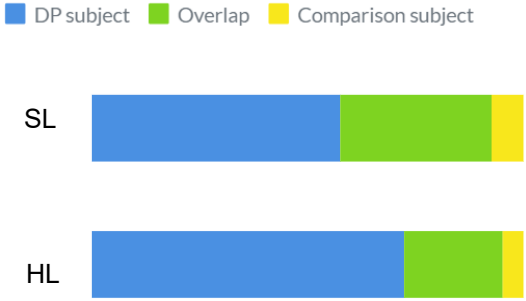
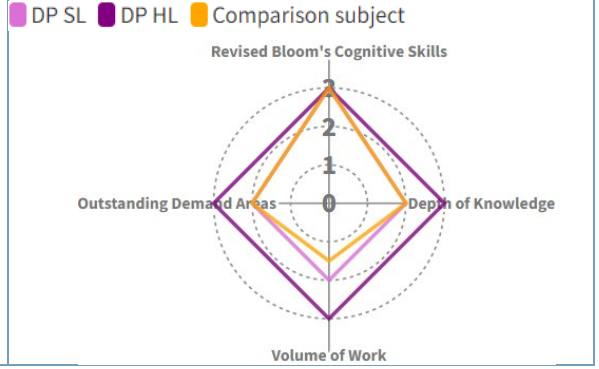
- **Differences in content:** the first-year SB biology, geology and environmental science subject does not cover a significant part of the DP biology's content, with SL content from four levels and AHL content from six levels having little or no presence in the SB. This is possibly a consequence of the combined nature of the course, as some time will be spent on subject areas outside of biology – i.e. geology and environmental sciences. The second-year SB biology subject shows greater alignment with the DP at SL, though seven levels show only partial alignment. With regards to AHL content, 11 levels show partial alignment in SB biology. Overall, the SB biology surpasses the DP SL in breadth and depth of content, and although it meets the breadth of the DP HL subject, it does not feature the same depth of content.

- **Differences in demand:** SB biology, as a whole, is exceeded by DP biology HL in all demand areas, though only for depth of knowledge and outstanding demand areas is the difference in scores a notable one.

5.9 Brazil

The subject level alignment between DP biology and BHSC Natural Sciences and Technology (NST) is represented below:

Figure 37: Visual representations of subject-level alignment (biology)

Subject name	Learning outcomes alignment	Content alignment*	Demand alignment
BHSC Natural Sciences and Technology (Basic General Education) *BHSC NST (BGE) Biology-focus*	Low / Moderate / **High**		
BHSC Natural Sciences and Technology (Formative Itinerary) *BHSC NST (FI) Biology-focus***	Low / Moderate / **High**		

*Biology content was broadly described in the documentation for BHSC NST. As such, specific concepts mentioned in DP biology topics were often not identifiable. Where there was limited reference to specific concepts, but broader evidence of coverage, it was concluded that the DP topic/subtopic was 'partially present' in BHSC NST. Therefore, the actual level of alignment may be slightly stronger, or weaker, than what is presented in these key findings.

**BHSC NST (FI) here represents the pathway of studying biology in basic general education and then specialising in a NST formative itinerary. The learning outcomes and demand conclusions for this pathway consider the NST formative itinerary component as a whole, whereas the content judgements only consider its biology content specifically (physics and chemistry content is not included).

- **Learning outcomes alignment**: the level of alignment between the learning outcomes of DP sciences and BHSC NST is high. Indeed, all DP sciences learning outcome themes are represented either completely or partially in the BHSC NST. Specifically, the themes of applying the elements that characterise science, using creativity and critical thinking, developing technological skills, and being aware of the issues and impacts of science, are all evident in the learning outcomes for BHSC NST. The DP themes of developing conceptual understanding and making connections, and of collaboration and communication, are also partially evident.

- **Content alignment**: the significantly more limited detail in BHSC NST documentation regarding the biology content to be covered poses a challenge when ascertaining the level of content alignment with DP biology. Generally, the documentation reviewed indicates that there is low-moderate content alignment between DP biology and BHSC NST, with the level of content alignment with DP biology being very similar for both BHSC NST (BGE) and BHSC NST (FI). There is partial presence of DP SL content from most DP biology levels in BHSC NST and very limited presence of AHL biology content. Where found, the levels within DP themes tend to have a 'partial', rather than 'strong', presence in BHSC NST – partially due to the BHSC describing the content in far less detail than the DP biology guide. As less biology content appears to be present, both BHSC NST (BGE) and BHSC NST (FI) are concluded to have less breadth and depth than DP biology SL and HL.

- **Demand alignment**: it can be noted that the demand scores for BHSC subjects are based on documentation which has somewhat limited detail regarding subject content. Generally, the documentation reviewed indicates that there is low-moderate alignment between the demand scores of DP physics and BHSC NST. Indeed, BHSC NST (BGE) scores lower than DP physics SL, whereas BHSC NST (FI) scores the same in most demand categories and is closely aligned with DP physics SL. The BHSC NST subjects do not align strongly with DP physics HL, as both BHSC NST (BGE) and BHSC NST (FI) have lower scores in most categories.

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

- **Similarities in learning outcomes**: the learning outcomes of BHSC NST have many similarities to those of DP sciences. BHSC NST learning outcomes similarly aim for students to use and apply knowledge and procedures typical of natural sciences (including scientific inquiry), use creativity and critical thinking, develop technological skills, and be aware of global and local problems and the impacts of science. Likewise, students are expected to develop conceptual understanding and communication skills, which partially reflects the DP learning outcome themes of developing conceptual understanding and making connections, and of collaboration and communication.

- **Similarities in content**: SL content from most levels in the DP biology themes is partially present in BHSC NST. Specifically, BHSC NST includes some SL content from all levels within C. Interaction and independence; most levels within A. Unity and diversity (Molecules, Cells and Ecosystems); and some levels within B. Form and function and D. Continuity and change (Molecules and Cells; and Organisms and

Climate Change, respectively). Additionally, the presence of scientific investigation in BHSC NST means that there are similarities with the DP's experimental programme, hence partial alignment with this component is concluded.

- **Similarities in demand**: BHSC NST (BGE) has the same demand score as DP biology SL for depth of knowledge. Generally, however, BHSC NST (FI) has stronger alignment with DP biology SL, as it receives the same scores for Bloom's cognitive skills, depth of knowledge, and outstanding demand areas. BHSC NST (FI) also shares the same score with DP biology HL for Bloom's cognitive skills.

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

- **Differences in learning outcomes:** The learning outcomes for BHSC NST place less emphasis on making connections between science subjects than the learning outcomes for DP sciences. Likewise, while BHSC NST learning outcomes require students to demonstrate respect and take part in group work, there is less explicit reference to the development of collaborative skills than in the DP. Finally, DP sciences outline specific experiments to be conducted, whereas – although scientific investigation is present – specific experiments are not detailed to the same extent in BHSC NST.

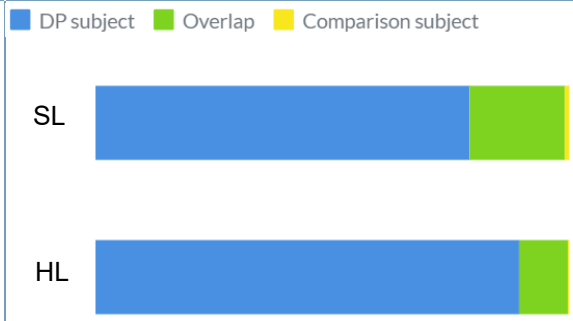
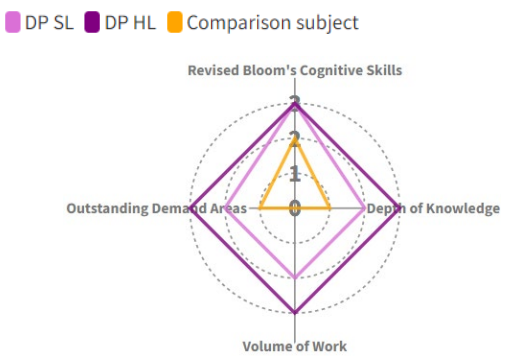
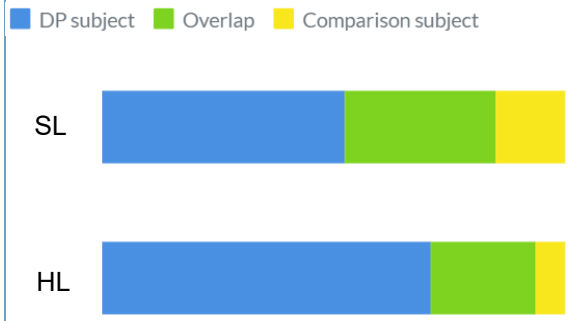
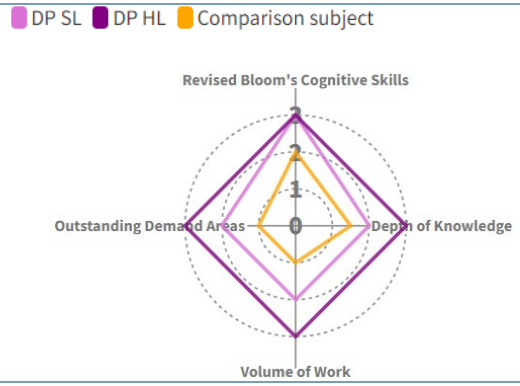
- **Differences in content:** Where alignments are found with the levels within the DP biology themes, these tend to be partial, as opposed to strong – though this is sometimes due to the limited detail available in the BHSC NST documentation. Moreover, there is little presence in BHSC NST of SL content from five DP levels – namely, A3. Organisms, B3. Organisms, B4. Ecosystems, D1. Molecules, and D2. Cells. Furthermore, there is very little DP AHL biology content in BHSC NST. BHSC NST (FI) does not present a stronger alignment with DP biology content than BHSC NST (BGE), as very few additional DP SL topics and AHL topics could be identified. BHSC NST (FI) offers specialisation in science generally, as opposed to biology specially, and provides an opportunity for students to extensively apply scientific concepts to a variety of contexts and issues. Finally, BHSC NST contains fewer mentions of specific experimental activities to be carried out compared to the DP's experimental programme.

- **Differences in demand:** There is an overall low-moderate alignment between the demand scores of DP biology and BHSC NST subjects. Indeed, BHSC NST (BGE) scores lower than DP biology SL for Blooms' cognitive skills, volume of work, and depth of knowledge. Furthermore, the demand scores for BHSC NST (BGE) are lower than DP biology HL for all demand categories. BHSC NST (FI) scores lower than DP biology SL for volume of work and lower than DP biology HL for depth of knowledge, volume of work, and outstanding areas of demand.

5.10 Mexico

The subject level alignment between DP biology and the MBG Natural Sciences, Experimental Sciences and Technology units (biology-focus) is represented below:

Figure 38: Visual representations of subject-level alignment (biology)

Subject name	Learning outcomes alignment	Content alignment*	Demand alignment
Compulsory Natural Sciences, Experimental Sciences and Technology Units (Biology)	Low Moderate **High**		
Compulsory and Optional Natural Sciences, Experimental Sciences and Technology Units (Biology)	Low Moderate **High**		

*The yellow bar for MBG Natural, Experimental Sciences and Technology units represents biology-only content, it does not represent health science topics

MBG Compulsory units: Matter and its interactions, Conservation of energy and its interactions with matter, Ecosystems: interactions, energy and dynamics, Chemical reactions: conservation of matter in the formation of new substances, Energy in the processes of daily life, Organisms: structures and processes, Science workshop I.

MBG Optional units: Selected Topics in Biology I & II.

- **Learning outcomes alignment**: the level of alignment between the science learning outcomes of the DP and MBG is significant. Indeed, all themes extracted from the DP sciences learning outcomes are present in the Natural Sciences, Experimental Sciences and Technology units of the MBG.

- **Content alignment**: the level of content alignment between MBG compulsory units and DP biology is low. While there is greater alignment with SL than HL, the MBG compulsory units only have alignment with the SL content in two of the levels within two themes - and such alignment is deemed to be only 'partial'. Overall, the MBG compulsory units have a lesser breadth and depth of biology content compared to DP biology SL and HL. While the MBG compulsory and optional units together have greater alignment with DP biology SL, the level of alignment with DP biology remains low. The MBG compulsory and optional units have at least partial alignment with SL content in half of the DP biology levels across the four themes and partial alignment with the AHL content of one level in two themes. Overall, the MBG compulsory and optional units have a lesser breadth and depth of biology content compared to DP biology SL and, particularly, HL.

- **Demand alignment**: there is an overall low level of alignment between the demand scores of DP biology and the MBG Natural Sciences, Experimental Sciences and Technology units. The DP biology receives higher scores in all categories than the MBG compulsory units. The MBG compulsory and optional units scores more similarly to DP SL, though it still scores lower than the DP in all demand categories.

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

- **Similarities in learning outcomes:** there is a high level of alignment between the learning outcomes of DP sciences and the Natural Sciences, Experimental Sciences and Technology units of the MBG. All themes extracted from the DP are strongly evidenced in the MBG compulsory units and optional units. There is particular emphasis in the MBG of the DP themes of conceptual understanding and techniques that characterise science and critical thinking, with the Extended Disciplinary Competences also highlighting the importance of conducting insightful investigations and having an awareness of the impact of science.

- **Similarities in content:** there is a small amount of overlapping content between DP biology and the MBG compulsory units. Indeed, the compulsory units have partial alignment with SL content from a few different DP levels – namely A2. Cells, A4. Ecosystems, C1. Molecules and C4. Ecosystems. The MBG compulsory and optional units combined have a greater amount of overlapping content with DP biology, as they cover more SL content and a small amount of AHL content. Indeed, the SL content of three DP biology levels (A2. Cells, A4. Ecosystems and C1. Molecules) is strongly present in the MBG compulsory and optional units combined, and the SL content of a further six DP levels is also partially present (these being A1. Molecules, B2. Cells, C2. Cells, C3. Organisms, C4. Ecosystems and D1. Molecules). Moreover, the compulsory and optional units combined include some DP AHL content from A3. Organisms and C2. Cells. It can be noted that, overall, the MBG units have strongest alignment with A. Unity and diversity and C. Interaction and interdependence. Lastly, the MBG units

(both compulsory and optional) have a strong presence of practical work and are, thus, judged to have strong alignment with the experimental programme component of DP biology.

- **Similarities in demand:** whilst there are no significant similarities between the demand scores of the DP and the MBG compulsory units, the MBG received a score of only one point below the DP SL for three categories. DP biology SL and the MBG compulsory and optional units received the closest score in the depth of knowledge category, where there is only a 0.5 difference between them.

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

- **Differences in learning outcomes:** there are no significant differences in the learning outcomes of DP sciences and MBG Natural Sciences, Experimental Sciences and Technology units.

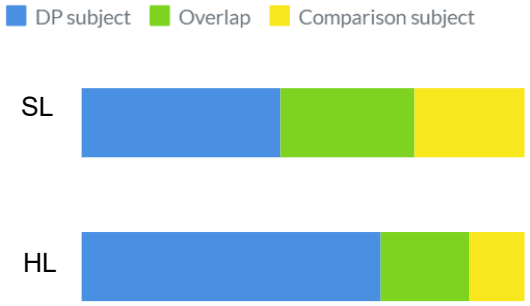
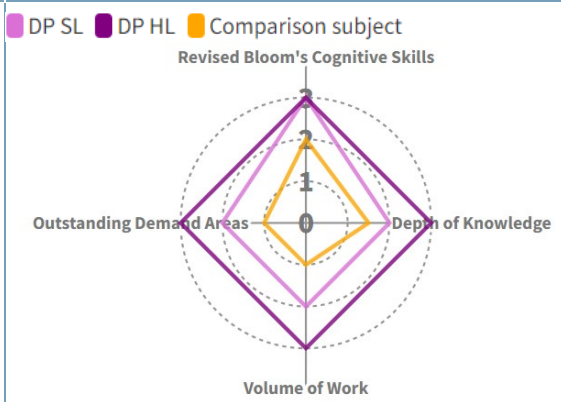
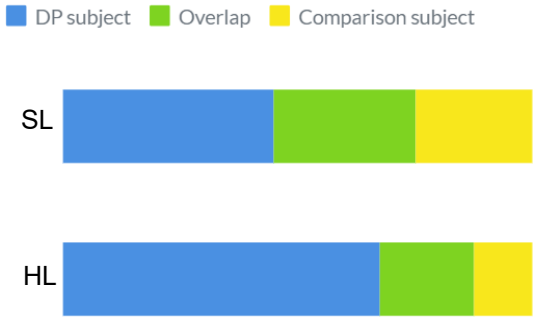
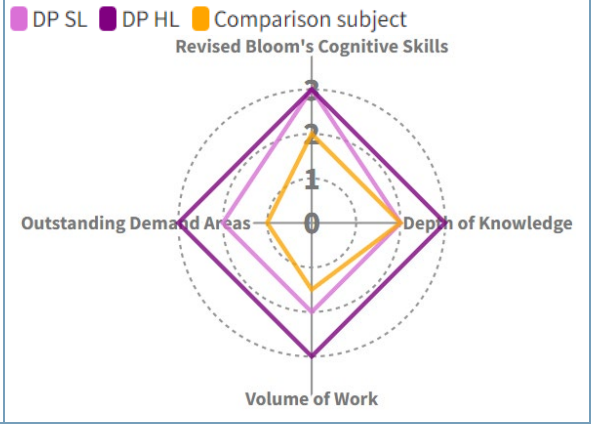
- **Differences in content:** content from a significant number of levels across the DP biology themes is absent from the MBG compulsory units. Indeed, the MBG compulsory units have no overlapping content with any of the levels from B. Form and function and D. Continuity and change. In addition, half of the DP biology levels from A. Unity and diversity and C. Interaction and interdependence are also absent from the MBG compulsory units. Moreover, the compulsory units do not contain any DP biology AHL content, nor do they feature any significant content that is not present in the DP. As such, the MBG compulsory units have a significantly lesser breadth and depth of biology content than DP biology SL and HL. Regarding the MBG compulsory and optional units combined, a significant amount of DP SL and AHL content remains absent. Indeed, the MBG units have no alignment with three out of four levels in B. Form and function and D. Continuity and change. In addition, the MBG compulsory and optional units combined have no alignment with the DP biology level A3. Organisms and very limited alignment with AHL biology content overall. Therefore, while having greater alignment with DP biology than the compulsory units alone, the MBG compulsory and optional units combined still have lesser breadth and depth than DP biology SL and, particularly, DP biology HL. That said, it can be noted that the MBG Health Sciences optional units have not been included in the analysis of content and may explain some of the differences in alignment. For example, the areas of the kidney and osmoregulation may be covered in the MBG Health Sciences units rather than the MBG Biology units. Lastly, within the MBG optional Biology units there is coverage of regulations for GMO product use in Mexico, which is not present in DP biology.

- **Differences in demand:** DP biology SL and HL score higher in all demand categories than the MBG Natural Sciences, Experimental Science and Technology units (biology-focus). The MBG compulsory units, and compulsory and optional units taken together, have received the same score of 2 for Bloom's cognitive skills, which is lower than both the DP SL and HL. DP biology also features greater breadth and depth, which is reflected in the higher scores for the volume of work and depth of knowledge categories. Moreover, DP biology courses have more required stretch areas than MBG units, resulting in higher scores for the outstanding demand areas category

5.11 Japan

The subject level alignment between DP biology (SL and HL) and JHSC biology subjects is represented below.

Figure 39: Visual representations of subject-level alignment (biology).

Subject name	Learning outcomes alignment	Content alignment*	Demand alignment
JHSC Advanced Biology	Low **Moderate** High		
JHSC Biology for the Science and Mathematics Course (SMC)*	Low **Moderate** High		

*The JHSC states that content may be expanded as appropriate in specialised science subjects such as Biology (SMC). Therefore, in practice, the subject content and demand may differ slightly to what is represented here.

- **Learning outcomes alignment**: There is a moderate level of alignment between the DP and JHSC science learning outcomes. The DP learning outcome themes tend to only be partially present in the JHSC objectives and two themes have little to no presence.

- **Content alignment**: JHSC biology subjects have low-moderate content alignment with DP SL biology content and limited alignment with AHL content. Advanced Biology covers less breadth than DP biology and less depth in some areas compared to SL. Biology (SMC) covers the same content, while allowing opportunity for expansion. Hence, the specialised subject may offer greater breadth and depth of content in practice.

- **Demand alignment**: JHSC biology subjects have moderate alignment with the demand scores of DP biology at SL and limited alignment with the demand scores of DP biology at HL. However, the specialised subject Biology (SMC) allows for expansion, hence there is scope for the demand to be greater in practice.

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

- **Similarities in learning outcomes**: The most significant similarity between DP and JHSC science learning outcomes is the emphasis on developing skills for scientific investigation. Indeed, the JHSC objectives expect students to formulate and verify predictions and hypotheses using observations and experiments throughout the subjects. The JHSC objectives also partially align with the DP themes of conceptual understanding, use and application of methods, tools, and techniques, and awareness of global and local issues and the impact of science.

- **Similarities in content**: JHSC biology subjects show the strongest alignment with DP biology theme *C. Interaction and independence.* The SL content from each level is at least partially covered, and the AHL content in *C3. Organisms* is also partially present. Additionally, there is partial coverage of the SL content in most levels of *A. Unity and diversity*, as well as some partial alignment with the AHL content in *A2. Cells*. Furthermore, the emphasis on scientific investigation in the JHSC results in a strong alignment with the DP's experimental programme.

- **Similarities in demand**: JHSC subjects score somewhat similarly to DP biology at SL for all demand categories, particularly for depth of knowledge. Biology (SMC) has slightly greater alignment with DP biology at SL, scoring the same or very closely for volume of work and depth of knowledge.

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

- **Differences in learning outcomes:** The DP themes of communication and collaboration and developing technological skills are not present in the JHSC objectives. Furthermore, the objectives place less emphasis on conceptual understanding, use and application of methods, techniques and tools, critical thinking skills, and awareness of issues and the impact of science.

- **Differences in content:** There is very little presence of content from the DP biology theme *B. Form and function* in the JHSC biology subjects. Furthermore, alignment is also limited with *D. Continuity and change*, as there is very little presence of content from the cells, organisms and ecosystem levels. In addition, other alignments with SL and AHL content are mostly partial, as often only some of the same understandings are covered.

- **Differences in demand:** JHSC subjects, particularly Advanced Biology, tend to score lower than DP biology subjects, particularly in comparison to HL.

6. Cross-cutting Findings

This section summarises the main cross-cutting trends, similarities and differences found when comparing the DP subjects against the comparison subjects in the eleven comparison programmes. In particular, the section focuses on the cross-cutting findings uncovered from the learning outcomes, content and demand analyses.

6.1 Learning Outcomes

Table 47: Presence of the DP's science learning outcomes in the comparison curricula

Themes extracted from learning outcomes of the DP sciences subject group	Presence in the comparison curricula										
	VCE (Victoria)	OSSD (Ontario)	FNCC/ GUSE (Finland)	SGA (Singapore)	KHSCG (South Korea)	NGSS (US)	FB (France)	SB (Spain)	BHSC (Brazil)	MBG (Mexico)	JHSC (Japan)
1. Conceptual understanding and making connections											
2. Use and application of knowledge, methods, tools, and techniques that characterize science											
3. Creativity and critical thinking (problem-solving, analysis, evaluation, synthesis)											
4. Skills for scientific inquiry											
5. Development of technological skills											
6. Effective collaboration and communication											
7. Awareness of global and local problems and the environmental, ethical, cultural, and social impact of science											

Key:

	This theme is well-evidenced in the learning outcomes of the comparison curriculum.		*This theme is partially evidenced in the learning outcomes of the comparison curriculum.*		*This theme is not evidenced in the learning outcomes of the comparison curriculum.*

The table above displays the themes extracted from the DP sciences subject group learning outcomes (which apply to biology) and summarises their presence in the biology curricula of the eleven comparison programmes/standards. Additionally, to complement the above, the table below lists any main themes found in the comparison curricula which were different to those of the DP, including any notable differences in emphasis or approach.

Table 48: Summary of different themes/emphases featured in the learning outcomes of the comparisons and not in the DP.

Comparison	Different themes/emphases to the DP
Australia (Victoria)	No other significant themes present.
Canada (Ontario)	Canadian contributions to biology and recognition of indigenous peoples' knowledge and customs. Bigger emphasis on careers.
Finland (FNCC)	The importance of collaboration with outside agencies such as local or international workplaces. The biological research that occurs in Finland and the importance of this.
Singapore (SGA)	No other significant themes present.
South Korea (KHSCG)	No other significant themes present.
US (NGSS)	More emphasis on being able to develop and use models and computational thinking.
France (FB)	More emphasis on oral presentations (due to the mandatory oral test) and convincing others of arguments.
Spain (SB)	Specific emphasis on the role of women in scientific research.
Brazil (BHSC)	The historic contextualization of scientific information including theories and laws proposed through history. The deliberate misuse of science for purposes of segregation, discrimination and deprivation of rights.
Mexico (MBG)	No other significant themes present.
Japan (JHSC)	No other significant themes present.

Regarding structure and presentation of learning outcomes, the DP, NGSS, and FB describe one set of outcomes which are applicable to all science courses in the programme – i.e. they do not outline specific outcomes for each course available in sciences. In contrast, all other comparison curricula have course-specific outcomes, with some featuring both overarching outcomes for the sciences subject area and course-specific outcomes. That said, the VCE, FNCC, KHSCG, and JHSC course-specific outcomes only slightly differ where they are contextualised for the content of the course. Similarly, the OSSD course-specific expectations are primarily content-focused. However, for SGA, SB, BHSC, and MBG, the course-specific outcomes describe somewhat different skills for each course, as well as content. For instance, the aims for SGA H2 and H3 are slightly different, as the latter builds on and extends knowledge and skills acquired in H2. Similarly, the outcomes for the SB are slightly different between the first and second year courses, as students move from a combined science course to a stand-alone biology course. Furthermore, the BHSC includes additional skills for formative itineraries and the MBG presents a different set of competencies for its optional units.

Generally, the comparison curricula feature similar learning outcome themes to those in the DP. In particular, the themes of *Using and applying knowledge, methods, tools, and techniques that characterise science*, *Creativity and critical thinking*, and *Skills for scientific inquiry* are strongly present in nearly all curricula. Other themes are generally present, though have partial or limited presence in three or four curricula.

In general, there are very few themes featured in the comparison curricula that are less emphasised or not present in the DP. However, one notable difference is the OSSD's greater national focus, placing significant emphasis on Canadian contributions to science and recognition of indigenous people's knowledge and customs. In addition, the latter also pays greater attention to careers, while the NGSS place stronger emphasis than the DP on using models and computational thinking. Finally, the FNCC puts particular emphasis on understanding how collaboration with outside agencies is important in gaining skills and knowledge in biology – a unique feature that does not receive the same level of attention in any of the comparison curricula. The BHSC places an emphasis on recognising the historic contextualisation of scientific information. For example, the BHSC includes an expectation for students to discuss models, theories and laws proposed in different times. Likewise, there is a greater emphasis in the BHSC on deliberate misuse of scientific knowledge, including where scientific knowledge has been used for the purposes of segregation, discrimination and the deprivation of rights.

Overall, there is generally a high degree of learning outcome alignment between the DP and comparison curricula. The DP and JHSC have the least alignment for learning outcomes, as the latter focuses on a narrower range of outcomes. While certain themes may be less present, the other curricula have strong alignment with the DP with regards to learning outcomes, particularly the VCE, OSSD, FNCC, KHSCG, and MBG.

6.2 Content

6.2.1 Structure

The DP offers two levels of biology study, SL and HL. Similarly, the option to study biology at different levels is offered across all comparison programmes (excluding the NGSS, which are not a full curriculum). This is done by offering subjects at different levels (as in the SGA) or by allowing students to choose how many biology/science courses they study.

While offering different levels of biology study, it is important to note that some of the curricula combine biology with other sciences in some or all of the courses they offer, in contrast to the DP which offers biology on its own. The combining of sciences is a particularly significant feature in the FB, SB, BHSC and MBG. The FB offers students a combined course (Life and Earth Sciences) in the first and second years. Moreover, the SB offers students a combined-style course (Biology, geology and earth sciences) in the first year of study, and then a specialist biology course in the second year. The MBG consists of core units which integrate the sciences and offers optional biology units in the final year. Lastly, the BHSC offers specialisation in the form of formative itineraries which combine physics, chemistry and biology.

In terms of how the content is structured within the courses, one feature that the DP shares with most of the comparison biology curricula is that all content within a specific course is compulsory. This feature is shared by most curricula subjects/courses, except for some in the FNCC and VCE, which feature optional topics and areas.

Like most comparison biology subjects, the DP breaks its biology content down into a small number of overarching subject areas, with each being further divided into topics. The exact

number of levels and topics varies somewhat across the curricula, however – e.g. some, like KHSCG Biology II, divide their biology content into only three topics, while others, such as the OSSD, divide it into six topics. However, DP biology is unique in its organisation of content into themes and levels.

Somewhat uniquely, DP biology's overarching themes and levels are the same for both SL and HL. Only the SGA takes a similar approach, featuring the same five overarching topic areas in both H1 and H2, though the latter includes an additional extension topic not featured in the former. This feature is not replicated across the rest of the comparison curricula, where different biology courses within the same programme have different overarching topics and thematic focuses.

As to how the levels and topics are presented, the DP and other curricula all similarly state these as succinct titles which describe the subject content. In contrast, the VCE uniquely describes its large topic areas (Areas of Study) using mostly guiding questions, such as 'How do organisms regulate their functions?'. The OSSD, in turn, presents more descriptive sub-topics than other curricula, detailing the concepts to be understood, links to technology, environment, and society, and the skills required for scientific inquiry. Furthermore, the BHSC content is not organised using biology topics but by specific competencies and skills for Natural Science and Technology, which are an integration of skills and physics, chemistry, and biology content.

Overall, the structure of the biology subject area and of each biology course within each curriculum varies significantly across the comparison programmes – with differences found in the number of biology subjects offered per programme; the overarching topic and sub-topic areas and whether these differ by course/level of study; the number of topics and sub-topics covered, as well as their optionality; and the level of detail used to describe each topic/sub-topic. Nevertheless, all (except the NGSS, which are standards rather than a programme of study) offer students the option to study biology in greater or lesser depth – some by allowing study at different levels, others by allowing students to study additional biology (or combined science) courses.

6.2.2 Content Alignment

The following tables summarise the presence of DP biology SL and AHL content in the biology curricula of the eleven comparison programmes/standards. Here, all biology content within each comparison curriculum is considered. To view the biology content within specific subjects, and how it aligns with DP biology, refer to the relevant country in Section 4. Subject-Level Alignment.

Table 49: Presence of DP biology SL content in the biology curricula of the eleven comparison programmes/standards[187]

DP biology themes and levels (SL content)		Presence in comparison curricula										
		VCE	OSSD	FNCC	SGA	KHSCG	NGSS	FB	SB	BHSC	MBG	JHSC
A. Unity and diversity	1. Molecules											
	2. Cells											
	3. Organisms											
	4. Ecosystems											
B. Form and function	1. Molecules											
	2. Cells											
	3. Organisms											
	4. Ecosystems											
C. Interaction and interdependence	1. Molecules											
	2. Cells											
	3. Organisms											
	4. Ecosystems											
D. Continuity and change	1. Molecules											
	2. Cells											
	3. Organisms											
	4. Ecosystems											
Experimental programme												

Key:

	Strong presence of this level in the comparison curriculum.		*Partial presence of this level in the comparison curriculum.*		*Little or no presence of this level in the comparison curriculum.*

[187] NB: only topics covered featured at the respective level (i.e. SL) have been included in the table.

Table 50: Presence of DP biology AHL content in the biology curricula of the eleven comparison programmes/standards[188]

DP biology themes and levels (AHL content)		Presence in comparison curricula										
		VCE	OSSD	FNCC	SGA	KHSCG	NGSS	FB	SB	BHSC	MBG	JHSC
A. Unity and diversity	1. Molecules											
	2. Cells											
	3. Organisms											
	4. Ecosystems											
B. Form and function	1. Molecules											
	2. Cells											
	3. Organisms											
C. Interaction and interdependence	1. Molecules											
	2. Cells											
	3. Organisms											
D. Continuity and change	1. Molecules											
	2. Cells											
	3. Organisms											
	4. Ecosystems											
Experimental programme												

Key:

	Strong presence of this level in the comparison curriculum.		*Partial presence of this level in the comparison curriculum.*		*Little or no presence of this level in the comparison curriculum.*

[188] NB: only topics covered featured at the respective level (i.e. AHL) have been included in the table.

The table below lists any significant content found in the comparison biology curricula which was not present in DP biology or covered differently.

Table 51: Topics which are not in the DP's content, or follow a significantly different approach

Comparison	Topics
VCE	No other significant topics present.
OSSD	No other significant topics present.
FNCC	Applications of biotechnology and their importance. The use of microbes in biotechnology.
SGA	Induced pluripotent stem cells and their use. Mosquitoes, malaria and dengue.
KHSCG	Biotechnology; its uses and importance in the medicine and food industries, as well as ecological, ethical, legal and social issues with it. Learning from biology throughout history and how biology is integrated into everyday life decisions such as food, clothes, make-up, architecture, transport and sports.
NGSS	No other significant topics present.
FB	No other significant topics present.
SB	Biotechnology; its importance and impact. Its uses in health, agriculture, the environment, new materials and the food industry. Detailed aspects of micro-organisms.
BHSC	Environmental policies and political considerations, for example evaluating political issues regarding the world's energy needs.
MBG	Genetic engineering, PCR, biotechnology and GMO products. Plants and fungi endemic to Mexico and the importance of their preservation.
JHSC	Mechanisms of evolution – genetic drift Genetic technology – restriction enzymes, vectors, and gene amplification techniques Animal behaviour and the relationship to the functioning of the nervous system Ecosystems – content on the nitrogen cycle.

Some content from each of the DP's four main themes of *A. Unity and diversity*, *B. Form and function*, *C. Interaction and interdependence*, and *D. Continuity and change* is found in most comparison curricula. This is generally true for both SL content and AHL content, except for the NGSS, BHSC, MBG, and JHSC. The NGSS features no significant AHL content from themes B and C, the BHSC does not include any AHL content, the MBG does not contain any AHL content from themes B and D, and the JHSC contains no significant SL or AHL content from theme B.

DP biology SL content is generally well-covered by most comparison curricula. The exceptions to this are the FNCC, BHSC, MBG, and JHSC. Coverage of SL content in *B. Form and function* and *D. Continuity and change* is particularly low in the MBG and JHSC.

With regards to DP biology AHL content, most comparison curricula cover at least some content from each of the DP's four main themes, with the exception of the NGSS, BHSC, MBG, and JHSC. However, across the curricula, this coverage of AHL content is less comprehensive than that of the SL content, with considerably more instances of no alignment or partial alignment found. The AHL content from *A1. Molecules*, *A4. Ecosystems*, and *C3. Organisms* is the least present across the curricula.

Regarding the experimental programme, there is some level of alignment between the DP and that of other curricula as experimental work is present in the comparison subjects of every programme/standards in this study. Alignment with the DP is particularly strong for subjects in

the SGA, KHSCG, MBG, and JHSC. The remaining comparison curricula are less explicit about what their experimental programmes cover.

When considering large topics or content areas which are present in the comparison curricula but not in the DP, this was mostly observed in the FNCC, SGA, KHSCG, SB, BHSC, MBG, and JHSC, with each containing topics which are not found in the DP. Most commonly, the content absent from the DP relates to aspects of biotechnology and its importance.

Overall, as can be seen in the tables, the OSSD, KHSCG, FB, and SB have the strongest content alignment with DP biology, as each includes a significant amount of SL and AHL content.

6.3 Demand

The following table provides a visual representation of the demand scores the expert panel awarded to the DP biology and respective comparison subjects in each of the eleven comparison programmes/standards.

Table 52: The demand scores of biology subjects from the DP and eleven comparison programmes

Demand category	Scores																		
	DP (IB)		VCE	OSSD		FNCC		SGA			KHSCG	NGSS	FB	SB	BHSC		MBG		JHSC	
	SL	HL	Bio.	G. 11	G. 12	C	All	H1	H2	H3	Biology	LS	LES	Bio.	BGE	FI	C	All	AB	S
Revised Bloom's Cognitive Skills	3	3	2.5	2	2.5	2	3	2	2	3	2	2	2	2.5	2.5	3	2	2	2	2
Depth of Knowledge	2	3	2	1.5	2	1.5	2	1	2	3	2	1	2	2	1	2	1	1.5	1.5	2
Volume of Work	2	3	1	2	2	1.5	2	1	2	3	2	0	2	2.5	0.5	1.5	0	1	1	1.5
Outstanding Demand Areas	2	3	0	0	1	1	1	0	1	1	1	0	1	2	1	2	1	1	1	1

Key:

VCE (Australia): Bio: Biology	**OSSD (Canada):** G.11: Grade 11 Biology G.12: Grade 12 Biology	**FNCC/GUSE (Finland):** C: Compulsory Biology modules All: Compulsory and optional Biology modules	**SGA (Singapore):** H1: Higher 1 Biology H2: Higher 2 Biology H3: Higher 3 Biology	**KHSCG (South Korea):** Biology: Biology I, Biology II, Integrated Science, and Scientific Investigation combined	**NGSS (US):** LS: Standards for Life Sciences
FB (France): LES: Life and Earth Sciences	**SB (Spain):** Bio: Biology	**BHSC (Brazil)** BGE: Basic general education FI: Formative itinerary	**MBG (Mexico):** C: Compulsory science units (biology) All: Compulsory and optional science units (biology)	**JHSC (Japan):** AC: Advanced Biology S: Biology for the Science and Mathematics Course	

Only a few curricula contain a subject which scores the same as DP biology for Bloom's cognitive skills (which obtained a score of 3 for this category). These lower scores in the rest of the curricula reflect a more limited presence of evaluation and creativity in their learning outcomes. However, it is worth noting that the difference in scores is often small, with the VCE, OSSD, SB, and BHSC having a subject which scores 2.5. None of the subjects/pathways examined score less than a 2, showing that analysis and some higher order thinking is present in the subjects of all curricula.

As can be seen in the figure above, most comparison curricula have at least one subject/pathway which scores the same as DP biology SL for depth of knowledge. The NGSS and MBG subjects score lower – partially because the lack of detail in the NGSS standards' documentation makes it difficult to ascertain their true depth. Only the SGA has a course that scores the same as DP biology HL for depth of knowledge (i.e. the maximum score for this category). Lastly, the NGSS, OSSD, SGA, FNCC, BHSC, MBG, and JHSC all have one subject/pathway which scores less than DP biology SL in this category.

When it comes to volume of work, a number of comparison curricula have courses that score the same as DP biology SL for this category – namely the OSSD, KHSCG, FNCC, FB and SGA. The SGA and SB have courses which score greater than SL, with SGA H3 scoring the same as DP biology HL for volume of work. Notably, a number of comparison programmes/standards offer subjects with a lower volume of work than both SL and HL, namely the VCE, FNCC, SGA, NGSS, BHSC, MBG, and JHSC.

All comparison curricula, except one, score lower than the DP in the category of outstanding areas of subject demand, compared to both SL and HL. Only the SB and BHSC have courses which score the same as DP biology SL.

In summary, whilst most comparison programmes/standards offer a biology subject that has good alignment with DP biology SL, only the SGA and SB offer a subject that has reasonable alignment with DP biology HL. Furthermore, outstanding areas of demand is the primary category in which comparison subjects score lower than the DP, with both SL and HL featuring a higher number of outstanding areas of subject demand than most.

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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 53: [Subject]

Demand Judgement	Score Descriptors (highlight the best-fit descriptor)	Judgement and Key Evidence
Revised Bloom's Cognitive Skills[189]	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[190]	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	

[189] Evidence pool: Learning outcomes
[190] 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[191]	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[192]	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)	

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

Appendix D

This appendix displays the BNCC's specific competencies and specific skills for Natural Sciences and Technology in high school.

Figure 40: Specific competencies and specific skills for Natural Sciences and Technology

1. Analyze natural phenomena and technological processes, based on the interactions and relations between matter and energy, to propose individual and collective actions that improve the production processes, minimize social and environmental impacts and improve local, regional and global living conditions.
(EM13CNT101) Analyze and represent, with or without the use of devices and applications transformations and conservations in systems that involve amount of matter, energy, and motion to make predictions about their behaviors in everyday situations and in production processes that prioritize the sustainable development, the conscientious use of natural resources and the preservation of the life in all its forms.
(EM13CNT102) Perform forecasts, evaluate interventions, and/or build prototypes of thermal systems aimed at sustainability, considering their composition and effects of thermodynamic variables on their functioning, also considering the use of digital technologies to assist in the calculation of estimates and to support the construction of prototypes.
(EM13CNT103) Use knowledge about radiation and its origins to assess the potentialities and risks of its application in equipment of daily use, in the health, the environment, industry, agriculture and electricity generation.
(EM13CNT104) Assess the benefits and risks to health and the environment, considering the composition, toxicity and reactivity of different materials and products, such as also the level of exposure to them, positioning oneself critically and proposing solutions individual and/or collective for their responsible use and disposal.
(EM13CNT105) Analyze biogeochemical cycles and interpret the effects of phenomena and human interference in these cycles, to promote individual actions and/or or collective ones that minimize harmful consequences to life.
EM13CNT106) Evaluate, with or without the use of digital devices and applications, technologies and possible solutions to the demands that involve the generation, the transportation, distribution and consumption of electricity, considering the availability of resources, energy efficiency, cost-effectiveness, geographical and environmental characteristics, waste generation and impacts socio-environmental and cultural aspects.
(EM13CNT107) Perform qualitative and quantitative forecasts on functioning generators, electric motors and their components, coils, transformers, batteries, batteries and electronic devices, based on the analysis of transformation processes and power conduction involved – with or without the use of devices and apps – to propose actions aimed at sustainability.
2. Analyze and use interpretations about the dynamics of Life, the Earth and the Cosmos to develop arguments, make predictions about the functioning and evolution of living beings and the Universe, and to support and defend ethical and responsible decisions.
(EM13CNT201) Analyze and discuss models, theories and laws proposed at different times and cultures to compare different explanations of the emergence and evolution of Life, of the Earth and the Universe with the currently accepted scientific theories.
(EM13CNT202) Analyze the various forms of manifestation of life in its different levels of organization, as well as the favorable environmental conditions and the with or without the use of digital devices and applications (such as simulation and virtual reality software, among others).
(EM13CNT203) Evaluate and predict the effects of interventions on ecosystems, and their impacts on living beings and the human body, based on maintenance mechanisms of life, in the cycles of matter and in the transformations and transfers of energy, using representations and simulations about such factors, with or without the use of digital devices and applications (such as simulation and virtual reality software, among others).

EM13CNT204) Elaborate: explanations, predictions and calculations regarding movements of objects on Earth, in the Solar System, and in the Universe based on the analysis of interactions with or without the use of digital devices and applications (such as simulation and virtual reality software, among others).
(EM13CNT205) Interpret results and make predictions about experimental activities, natural phenomena and technological processes, based on the notions of probability and uncertainty, recognizing the explanatory limits of the sciences.
(EM13CNT206) Discuss the importance of preserving and conserving biodiversity, considering qualitative and quantitative parameters, and evaluate the effects of the action and environmental policies to ensure the sustainability of the planet.
(EM13CNT207) Identify, analyze and discuss vulnerabilities linked to experiences and to the contemporary challenges to which young people are exposed, considering the physical, psycho-emotional and social aspects, in order to develop and disseminate prevention and promotion of health and well-being.
(EM13CNT208) Apply the principles of biological evolution to analyze history human origin, considering its origin, diversification, dispersion across the planet and different ways of interacting with nature, valuing and respecting ethnic diversity and human culture.
(EM13CNT209) Analyze stellar evolution by associating it with the models of origin and distribution of chemical elements in the Universe, understanding their relationships with the conditions necessary for the emergence of solar and planetary systems, their and compositions and the possibilities of the existence of life, using representations and simulations, with or without the use of digital devices and applications (such as software simulation and virtual reality, among others).
3. Investigate problem situations and evaluate applications of scientific knowledge and its implications in the world, using procedures and languages of the Natural Sciences, in order to propose solutions that consider local, regional, and/or global demands, and communicate their findings and conclusions to varied audiences, in different contexts and through different media and digital information and communication technologies (DICT).
(EM13CNT301) Construct questions, develop hypotheses, predictions and estimates, employ measuring instruments and represent and interpret explanatory models, data and/or experimental results to construct, evaluate and justify conclusions in coping of problem situations from a scientific perspective.
EM13CNT302) Communicate, to varied audiences, in different contexts, the results of analyses, research and/or experiments, elaborating and/or interpreting texts, graphs, tables, symbols, codes, classification systems and equations, by means of different languages, media, digital information and communication technologies (ICTs), in order to participate in and/or promote debates on scientific and/or technological topics of socio-cultural and environmental relevance.
(EM13CNT303) Interpret texts of scientific dissemination that deal with themes of the Natural Sciences, available in different media, considering the presentation of the data, both in the form of texts and in equations, graphs and/or tables, consistency of the arguments and the coherence of the conclusions, in order to construct selection strategies from reliable sources of information.
(EM13CNT304) Analyse and discuss controversial situations on the application of knowledge in the field of Natural Sciences (such as DNA technologies, stem cell treatments, neurotechnologies, production of defense technologies, pest control strategies, among others), based on consistent arguments, legal, ethical and responsible, distinguishing different points of view.
(EM13CNT305) Investigate and discuss the misuse of knowledge from the sciences of Nature in the justification of processes of discrimination, segregation and deprivation of individual and collective rights, in different social and historical contexts, to promote equity and respect for diversity.
EM13CNT306) Assess the risks involved in everyday activities, applying knowledge of the Natural Sciences, to justify the use of equipment and resources, as well as safety behaviors, aimed at physical integrity, individual and collective, and socio-environmental, being able to make use of devices and applications that enable the structuring of simulations of such risks.
(EM13CNT307) Analyze the properties of materials to assess the suitability of their use in different applications (industrial, everyday, architectural, or technological) and/or or propose safe and sustainable solutions considering their local and everyday context.

(EM13CNT308) Investigate and analyze the operation of electrical equipment and/or electronics and automation systems to understand contemporary technologies and assess their social, cultural, and environmental impacts.
(EM13CNT309) Analyze related socio-environmental, political and economic issues the dependence of today's world on non-renewable resources and discuss the need to introduce alternatives and new energy technologies and materials, comparing different types of engines and new production processes materials.
(EM13CNT310) Investigate and analyze the effects of infrastructure programs and other basic services (sanitation, electricity, transportation, telecommunications, vaccination coverage, primary health care, and food production, among others) and identify local and/or regional needs in relation to these services in order to evaluate and/or promote actions that contribute to the improvement of quality of life and health conditions of the population.